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MEDICAL USES OF RADIUM AND RADIUM SUBSTITUTES

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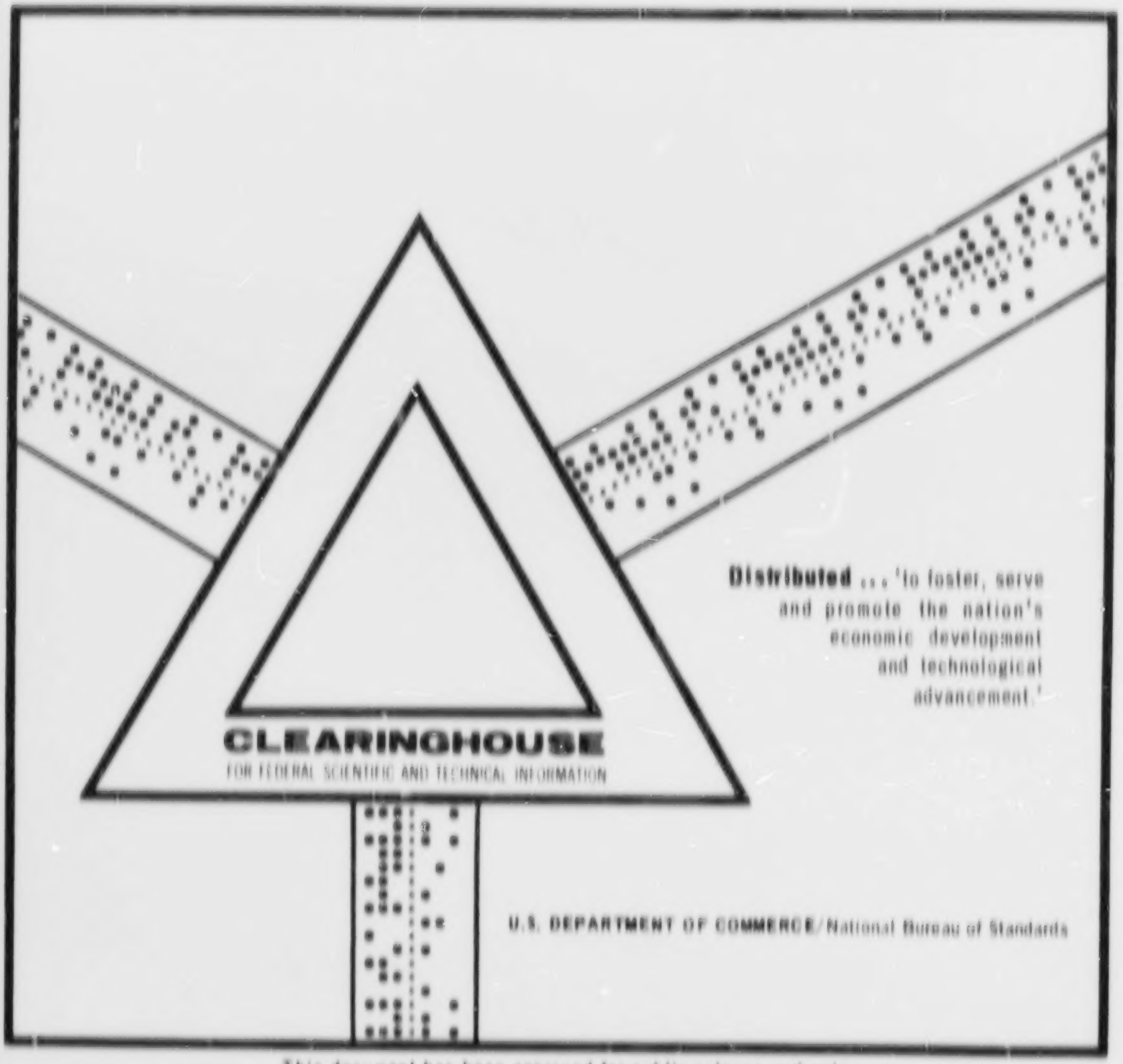
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ENVIRONMENTAL HEALTH SERIES
Radiological Health

MEDICAL USES OF RADIUM AND RADIUM SUBSTITUTES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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MEDICAL USES OF RADIUM AND RADIUM SUBSTITUTES

Report of the summary and conclusions of the Conference on Medical Uses of Radium and Radium Substitutes held at The Center for Continuing Education, University of Chicago, September 3–4, 1964.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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ABSTRACT

Representatives from professional medical societies, leading therapy centers, and governmental agencies attended a 2-day conference, September 3–4, 1964, sponsored by the Division of Radiological Health of the Public Health Service to discuss programs dealing with the management of radium and radium substitutes for medical uses.

The discussions were excerpted from the transcript and organized under the five conclusions reached by the conference. These conclusions indicate a need for comprehensive regulatory programs for radium, sealed source design standards for radium, adoption of suitable radium substitutes, research efforts toward developing better and safer sealed sources, and promotion of therapeutic techniques that will reduce radiation exposure to medical personnel.

INTRODUCTION

The National Advisory Committee on Radiation, of the Public Health Service, recently reviewed information on contamination problems arising from the use of radium in medicine. On the basis of the review, the Committee recommended that the Service investigate the practicality and means by which less hazardous, but equally effective, radioactive materials can be utilized in medicine. Acting upon this recommendation, the Public Health Service requested the various professional organizations, whose members had the widest experience with radium and other radionuclides used in medicine, to designate representatives whose individual and collective judgments could provide expert professional guidance to the Service. As a first step, the Division of Radiological Health of the Public Health Service sponsored a conference, under the chairmanship of Dr. Wendell Scott, for the mutual exchange of information on radium and radium substitutes.

At the conference, the Division of Radiological Health presented a summary of information obtained from a review of past radium incidents and accidents and from State health agencies who have been working with the medical profession in solving problems of radium contamination. Participants discussed and commented on the material presented and considered possible solutions.

The Division of Radiological Health is publishing the proceedings of the conference in the belief that those interested in the subject will find the discussion and conclusions instructive and useful. This report has been organized with an initial summary section which identifies the conference purpose, conclusions, and participants. The following text covers opening remarks of the participants, reflecting both individual viewpoints and the interests of the groups represented concerning the problem. Using the five conference conclusions as topic headings, those comments that are considered to be most valuable as guidelines in radium management have been excerpted from the transcript of the meeting and are reproduced herein with the approval of the participants.

CONCLUSIONS OF CONFERENCE

1. All naturally occurring radionuclides, including radium, radon, mesothorium, and so forth, as well as accelerator-produced radionuclides, should be subject to the same radiation protection regulations as are reactor-produced radionuclides.

2. Because of the special contamination hazards associated with radium, due to its physical and chemical properties, minimum standards of source design, construction, and testing should be established for this radionuclide by a body of appropriate experts.

3. A suitable substitute for radium, with less contamination hazard, is desirable. Because of the large body of clinical experience accumulated with radium, substitute sources should be made available which conform to the dimensions and dose distribution patterns of existing radium sources. Cesium 137 sources seem capable of satisfying these requirements. For temporary interstitial treatments where flexibility and shielding are important considerations, iridium 192 is the isotope of choice at the present time. For permanent implantation, gold 198 is a suitable substitute for radon. The use of radium plaques should be discontinued; strontium 90 plaques are a suitable substitute.

4. It is further recommended that research be directed to the development of better radiation sources for brachytherapy. The possibility of fabricating better and safer sources with presently used radionuclides, including radium, should be considered.

5. The development of new techniques, such as afterloading procedures, to reduce unnecessary personnel exposure in the therapeutic application of radionuclides should be supported and encouraged.

PARTICIPANTS

Following is a list of participants of the conference and the organizations they represented:

ANEL, N. AHNEMUN, M.D.,* Professor in Clinical Obstetrics and Gynecology, Associate Professor in Clinical Radiology, Washington University School of Medicine, St. Louis, Mo.—American Gynecological Society.

ARNOLD BERMAN, M.S., Chief, Thermal Applications Branch, Division of Isotopes Development, U.S. Atomic Energy Commission, Germantown, Md.—U.S. Atomic Energy Commission.

HARRY L. BERMAN, M.D., Chief, *Radiotherapy Section*, Sinai Hospital of Baltimore, Baltimore, Md.—American Roentgen Ray Society.

JOHN BOLAND, M.D., Radiotherapist-in-Chief, Mount Sinai Hospital, New York, N.Y.—Mount Sinai Hospital.

GILBERT H. FLETCHER, M.D.,* M. D. Anderson Hospital and Tumor Institute, Texas Medical Center, Houston, Tex.—American Radium Society and American Club of Therapeutic Radiologists.

FRANK HENSCHKE, M.D.,* Associate Professor of Clinical Radiology, Memorial Hospital for Cancer and Allied Diseases, New York, N.Y.—Memorial Center for Cancer and Allied Diseases.

GEORGE C. LEWIS, JR., M.D., Professor and Chairman, Department of Obstetrics and Gynecology, Hahnemann School of Medicine, Philadelphia, Pa.—American College of Obstetrics and Gynecology.

S. ALLAN LOUGH, Ph.D., Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington, D.C.—U.S. Atomic Energy Commission.

IRVIN M. LOURIE, M.D., Chief, Radiation and Isotopes Unit, Pan American Health Organization, World Health Organization, Washington, D.C.—Pan American Health Organization.

RUSSELL H. MORGAN, M.D., Radiologist-in-Chief, Johns Hopkins Hospital, Baltimore, Md.—*National* Advisory Committee on Radiation.

ROBERT G. PARKER, M.D., Chief, Division of Radiation Therapy, University of Washington, Seattle, Wash.—Association of University Radiologists.

ANTOLIN RAVENTOS, M.D.,* Professor of Radiology, University of Pennsylvania, Philadelphia, Pa.—Hospital of the University of Pennsylvania.

MILFORD D. SCHULZ, M.D.,* Department of Radiology, Harvard Medical School, Massachusetts General Hospital, Boston, Mass.—American College of Radiology.

WENDELL G. SCOTT, M.D., Professor of Clinical Radiology, Washington University School of Medicine, St. Louis, Mo.—American Cancer Society.

MICHEL TER POGOSSIAN, Ph.D., Professor of Radiophysics, Washington University School of Medicine, St. Louis, Mo.—Mallinckrodt Institute of Radiology.

*Also served as member of committee drafting conference conclusions.

Other persons attending the symposium, from the Public Health Service, were—

DONALD H. CHADWICK, M.D., Chief, Division of Radiological Health, Washington, D.C.

ROBERT H. GOEKE, M.S., Deputy Chief, State Assistance Branch, Division of Radiological Health, Washington, D.C.

PAUL HAHN, Ph.D., Chief, Research Grants Staff, Division of Radiological Health, Woodmont Building, 8120 Woodmont Avenue, Bethesda, Md.

PHILIP H. HUGILL, M.S., Assistance to State Radioactive Materials Program, Division of Radiological Health, 1901 Chapman Avenue, Rockville, Md.

MARTHA I. PHILLIPS, M.S., Training Grant Officer, Cancer Control Branch, Division of Chronic Diseases, Washington, D.C.

RUSSELL I. PIERCE, M.D., Chief, State Assistance Branch, Division of Radiological Health, Washington, D.C.

JOHN C. VILLFORTH, M.S., Chief, Assistance to State Radioactive Materials Program, Division of Radiological Health, 1901 Chapman Avenue, Rockville, Md.

OPENING REMARKS

CHAIRMAN

DR. SCOTT: Gentlemen, you may wonder particularly why I was chosen to be chairman of this meeting. I think it is, largely, not because I have any background as an expert in radium, but rather because of my interest in radiation protection and also because I, in association with the Missouri Atomic Energy Commission, realized the problems that are inherent with any State taking over the AEC regulations and responsibilities for all forms of radiation and particularly for radioisotopes. This takeover has presented a great many problems, many of which, I am sure, some of you are not aware. It has also presented opportunities for some form of control over all sources of radiation, including radium. These are the problems that we would like to discuss.

Now, Dr. Donald Chadwick has asked that this simply be a conference for general information, and there is no formal agenda. We are going to try to keep an orderly discussion and also to keep the discussions pertinent to the questions that are before the group so that we can move along as efficiently and effectively as possible.

PHS DIVISION OF RADIOLOGICAL HEALTH

DR. CHADWICK: As a prelude or background to discussing the events that led up to this meeting, for those of you who don't happen to be familiar with our division of the Public Health Service, I will try to sketch what we do very briefly just to give you a framework in which to consider our role in this present meeting.

Our Division of Radiological Health is in the Bureau of State Services of the Public Health Service, that part of the Public Health Service that works most closely with the State health departments. We have at the present time an annual budget of about $20 million and a staff of about 800. Our program can be divided into four general areas of activity.

The first of these is a research program. This research program is both intramural and extramural. In other words, we have a research grant program analogous to the research grant program of the National Institutes of Health. Our total research program is about $6 million, with roughly $5 million extramural and $1 million intramural.

There are two directions to our research effort. One is to try to develop more information on the effects of radiation on man. In that particular activity, we are greatly concerned with epidemiological studies of groups that have been exposed to more than the usual amounts of radiation to attempt to see whether any deleterious effects have occurred in these groups.

The other part of our research program is to develop methodology for reducing exposure where this is feasible and necessary. In this regard, we have been concerned with trying to develop means by which exposures of the population to fallout can be reduced at times when this becomes necessary. Perhaps some of you are familiar with some of the techniques which are being developed. In Missouri, for instance, we now have a large commercial dairy plant evaluating the ion-exchange strontium 90 removal process. We also have worked on some means by which radioiodine can be either prevented from getting into milk or removed from milk.

So this, then, very briefly, is the kind of thing that we do in our research program.

Then, secondly, we have a fairly large training effort. The training is directed primarily toward people in the field of what we call radiological health. There are many different terms here that apply to the same general area, but our term is "radiological health specialists." In this program, we have again what might be called both an intramural and then an extramural program. We have a $2.5 million a year grant program to universities for the training of radiological health specialists. Here, we are concerned primarily with the training of specialists for work in State and local health agencies, although many of the people who come out of these programs also work in hospitals and industry.

The other part of our training program is an intramural program. Here we carry on short courses for, again, primarily State and local health agency personnel; but many others also come into these programs. The training activities are carried on in a Public Health Service laboratory in Cincinnati, Ohio, and also in our Rockville laboratory near Washington.

The third activity is measurement and surveillance. Here we have programs designed to measure the exposure of the population to radiation from all sources. Many of our activities to date have been concerned with measurement and surveillance in connection with fallout from nuclear weapons testing. We have several national networks for sampling various media to give us an estimate of the exposures of the population. The most important one, perhaps, is our pasteurized milk network which samples the milk consumed by about a third of the population in the United States and, thus, gives us a fairly good

handle on the intake of radioactive materials from fallout, at least through the route of milk.

In the measurement surveillance area, we are also carrying out a study designed to provide some estimates of exposure of the population from medical and dental X-rays. As most of you know, this has been a controversial subject in recent years, dating back to the National Academy of Sciences report in 1956 which put out an estimate of the exposure. Many people have felt that this estimate was too high. Estimates in other countries were considerably lower. We are now trying to provide a better estimate of the exposure of the population in this country. We also hope that it will give some indication of how efforts might be carried out to improve the use of X-rays, not only to get better diagnostic results but also, hopefully, to reduce exposures where possible.

Finally, we have a program of assistance to State health agencies. This is the program that really is of most concern to us today, because problems raised by State health agencies indirectly led to the meeting that we are having today. Briefly, we have two elements to this State assistance effort.

First of all, we help the States directly through financial grants to State health agencies for the development of programs of radiation control. This is at the level of $2.5 million a years, at the present time, and is divided among the States on the basis of their population and financial need as well as the extent of the radiation problem.

Then, we also have our own internal program of technical assistance to States. And, as I have indicated, in just a moment we will be discussing one aspect of that technical assistance program at some length. Indeed, it was in response to requests from State health agencies for assistance in dealing with certain of the radium contamination problems which were coming to their attention that led us to develop a program within our own division to provide this assistance to the States. The States, of course, are becoming more and more concerned with this as their programs develop, and also as agreements are made between the Atomic Energy Commission and the States.

This is something I suspect some of you are familiar with. These agreements provide for the transfer of the regulatory responsibility that AEC has over isotopes to State health agencies on the satisfaction of certain AEC requirements.

In the process of taking over this AEC isotope responsibility, States have also been expanding activities in the area of radium. And thus, with many of the problems that have arisen, they have come to us asking for assistance. We have developed as much information as we could, some of which will be presented to you this morning.

We discussed this problem with our National Advisory Committee on Radiation, of which Dr. Russell Morgan is chairman. He will be discussing both NACOR and also the considerations that led NACOR to make the recommendation that we look into this problem.

Then, as you know, we felt that we wanted to discuss this radium situation with the people who knew the most about it and had the most information on the subject. So, the Surgeon General requested each of the professional societies considered most directly involved to designate representatives. Today's meeting is to provide an opportunity for exchange of information. We will present the data we have on the problems that have arisen and have been referred to us by State health agencies. We want the opportunity to discuss these problems with the people in the field, and then, also, we want to have the chance to hear some of the thinking that has been going on in the field among medical users.

And so, we regard today's meeting essentially as an opportunity for exchange of information and as possibly pointing ultimately to where we go from here.

DR. SILVER: I think we might call on Dr. Russell Morgan now to tell us a little bit about the background of NACOR, or the National Advisory Committee on Radiation, the chairmanship of which he has held for a number of years. It has been under the able guidance of NACOR that many of the policies were formulated and the recommendations made to the Surgeon General that led to the formation of the Division of Radiological Health and its objectives and goals. And in this direction, NACOR has done a terrific job. They have been a source of ideas and strength and stability in a period when there was so much discussion about the fallout. I had the opportunity of being a member of this committee for 8 years and saw it in action. I think you should know a little bit about this committee and its interest in this problem.

NATIONAL ADVISORY COMMITTEE ON RADIATION

DR. MORGAN: Perhaps a number of you are not too familiar with NACOR. Hence, at the outset, it might be well for me to give you a little background of its origin.

NACOR is a relatively young committee, compared to many others in the radiation field. In 1958, Dr. Leroy Burney, who was then the Surgeon General of the Public Health Service, became increasingly concerned regarding population exposures from ionizing radiation. Since I had known Dr. Burney for a number of years, from the time I was in the Public Health Service, he called me to ask that I advise

him on what programs he might develop in the Public Health Service to deal with problems of undue radiation exposure in the population. At that time, there was a modest effort being conducted by the Service in the radiation health field. Dr. Chadwick was identified with this. Mr. Terrill who is not able to be with us today was also involved.

Even though these modest activities were going on, they were insufficient to meet the needs of the Surgeon General. Hence, after discussions with a number of people in the radiation field, he decided to establish an advisory committee, called the "National Advisory Committee on Radiation," to serve as his principal advisor in connection with problems associated with population exposures from ionizing radiation.

This committee at the outset was made up of a wide spectrum of interests. The initial members included not only representation from clinical radiology—but also from radiobiology, genetics, radiation physics, sanitary engineering, public health, and industry. In some cases where there was a particularly broad interest developing, there were two representatives from a particular field.

The committee's first task was to help the Surgeon General to define clearly the role of the Public Health Service in the field of radiological health. Its first report was essentially devoted to this subject.

Simultaneously, with the development of NACOR, the Surgeon General placed on a more fully organized basis, the radiological efforts in the Public Health Service. The Division of Radiological Health was formed under Dr. Francis Weber, the division that Dr. Chadwick now heads.

Since its inception, NACOR has advised on a number of problems. One of these, as Dr. Chadwick has pointed out, is the problem of the hazards of radium and radium usage.

In the early 1960's, the Division of Radiological Health and the Surgeon General began to receive increasing numbers of requests from State health agencies, asking for guidance on meeting problems resulting from the misuse of radium. In 1963, Mr. Vilforth who will speak to you in a few minutes, presented to NACOR a summary of his findings following a study of these problems. As a result of that presentation, NACOR recommended to the Surgeon General "that the Division of Radiological Health actively explore means by which less hazardous radionuclides can be substituted for radium and its daughter products in medicine and industry."

I may say, parenthetically, that it was the wish of NACOR that the Division of Radiological Health should examine the radium problem from its broadest possible aspects—the development of improved methods of control of the conditions under which radium is employed and better screening of physicians who use radium, in addi-

tion to the matter of substitutes. NACOR was interested, and it felt that the Surgeon General should be interested in the problems of radium hazard from the broadest point of view. And I think that this is is the manner in which the Division of Radiological Health has been directing its efforts.

REVIEW OF PROBLEM

MR. VILLFORTH: In early 1962, it was apparent to the Division of Radiological Health that the State health departments were becoming increasingly involved with another radiological health problem beside fallout—radium management.

This increasing involvement was partly stimulated by Public Law 86-373 which provides for the transfer of regulatory responsibilities for the control of AEC licensed isotopes to certain States. As part of this responsibility, the State health departments felt that a comprehensive radioactive materials program should include radium. However, as State health departments carried out radium management programs, they found there were many questions which needed answering.

Therefore, in attempting to answer some of these questions, we felt it necessary to see how significant the radium problem was in relation to the use of other radioactive materials. We began by assembling information from those States that were registering or licensing users of radium, and from a review of the literature. From various references, the national inventory of radium has been estimated to be approximately 2,000 grams. United States production has amounted to 200 grams and about 1,800 grams have been imported. That's not very much activity compared to the millions of curies of reactor-produced materials in use today. The radium problem becomes more significant when you consider that we have been able to account for only about 700 of the 2,000 grams in the United States. That is to say, the number of identifiable sealed sources in use constitutes approximately 700 grams. Of the remaining 1,300 grams, we believe that perhaps 65 to 70 percent have gone into various luminous compounds for use on wrist watches, aircraft instruments, etc. A significant quantity was thus used during both World Wars for many kinds of military instruments. When we examine the 700 grams that are identifiable, we find them in use at approximately 4,500 facilities. These are broken down into approximately 1,000 hospitals and clinics, 1,700 private practitioners, and about 1,800 industries, research institutions, and educational institutions. This total group of 4,500 is equivalent in number to about 45 percent of the AEC licenses.

CHARACTERISTICS OF RADIUM

Physical and Chemical Characteristics	*Results*
1. Radium is an alkaline metal that reacts with nitrogen; therefore, it is used only in the form of salts.	If a source ruptures, the salts are easily dispersed. The salts may "pack" in a needle, causing a nonlinear distribution.
2. The salts are usually bromides, chlorides, sulfates, or carbonates.	Salts are soluble in amounts that are radiotoxic.
3. Radium is chemically like barium.	Like barium and calcium, it concentrates in the bone.
Radiological Characteristics	*Results*
1. Radium has a long half-life (1,602 years).	This increases the radiotoxicity if radium is ingested.
2. Radium decays through a complex series of radioactive daughter products.	
a. The first daughter in the series is the noble gas radon.	Radon is easily dispersed because it is chemically inert.
b. The daughters of radon are gamma emitters.	Loss of radon from a sealed source results in loss of gamma activity of the source.
c. In addition to the beta and gamma emission of the daughter products there are four alpha disintegrations for every initial radon 226 disintegration.	The alpha emission increases the biological hazard if the radium is ingested. It also transforms into helium gas causing pressure buildup in a sealed source.
3. Alpha activity decomposes water into hydrogen and oxygen.	These decomposition products produce pressure in a sealed source.

Now, in reviewing the problems associated with radium, it is desirable to look at some of its physical, chemical, and radiological characteristics. I have summarized these in a table [see above].

The fact that radium is an alkaline metal, and readily combines with nitrogen in the atmosphere, makes it relatively impossible to use in its elemental form. Instead, it must be used as a salt; the salts are usually chlorides, bromides, carbonates, and sulfates. Radium chloride and bromide are easier to produce, but have the inherent disadvantage of being very soluble in water and, of course, in body fluids. Radium sulfate and radium carbonate are very insoluble, but require an additional step in processing.

Radium is identical to barium chemically; that is, there is no chemical way of separating radium and barium. Thus, radium, like barium and calcium, will concentrate in the bone where it will be exchanged very slowly.

Radium in the presence of water or moisture will decompose the water into hydrogen and oxygen gas. Therefore, if radium is improperly dried when it is encapsulated, the gaseous decomposition products can increase the internal pressure of the capsule leading to leakage or rupture.

The radiological characteristics of radium are also interesting. The long half-life, which makes radium desirable as a tool in medicine, complicates decontamination and increases its radiotoxicity. The complex radioactive decay, through a series of daughter nuclides, has certain disadvantages, particularly since the first daughter is radon. Radon is an inert gas which may be easily dispersed throughout a facility should the radium source rupture. The radioactive daughter products of radon compound the contamination problem.

The gamma activity of radium is associated with the radon daughter products. This means that, should the radon gas leak from the containing capsule or needle, and become dispersed, the gamma activity of the source will be reduced. The result is that the medical usefulness of the source is lessened without the physician's knowledge that this has occurred.

In addition to the chemical, physical, and radiological characteristics, there is another aspect—perhaps it should be called an economic characteristic—that further compounds the radiological health problem from radium. If we look at the history of radium, we find that after World War I radium cost over $100 a milligram; the limited supply and tremendous demand inflated the cost. A physician who owned an inventory of radium at that time was someone to be envied. In recent decades, improved processing techniques and the discovery of new deposits of high grade uranium-bearing ores, has reduced the cost to between $16 and $21 a milligram.

To the best of my knowledge, there is no new radium processed in the United States today. I believe this is also the case in Canada. Most of the radium that is sold today comes from the reprocessing of old radium or from that which is left in the reserves of the radium companies.

This drastic reduction in the monetary value of radium means that physicians who purchased radium when the price was inflated may be reluctant to dispose of it at a much reduced price. Consequently, we have a sort of a radiological "white elephant." We might look for these "white elephants" in safety deposit boxes and in attics. And, oddly enough, radium sources have been found in these locations.

Now, in addition to this, is the fact that the manufacture and use of radium has not been regulated by any agency, certainly not by the Federal Government, and only recently by some States. Therefore, the only way that radium was handled and used properly was through a system of self-policing and education of the users. This has often been ineffective, and has led to some of the unfortunate experiences which we have documented.

To see how extensive this type of mismanagement was, we asked the various State health departments for information on their experience with incidents and accidents involving these sources. We also perused the literature for similar information.

It might be argued that a review of past incidents has no value under present conditions, since we have gained more knowledge on radiation protection and developed sophisticated instrumentation in the last decades. The so-called Geiger counter wasn't developed until the 1930's. In the early days, lost radium was located with electroscopes, photographic plates, or chunks of fluorescent ores like willemite. This was no easy task.

The knowledge that has been amassed about biological effects is considerable. Remember that although the external effects of radiation were known soon after its discovery, it wasn't until the middle 1930's that the radium-dial painting incidents of New Jersey suggested that the ingestion and inhalation of radium might have adverse biological effects.

We find that in spite of these things—the increased knowledge of radiobiology and radiation protection, and the more sophisticated inspection and monitoring instruments—the misbandling of radium and the incidents and accidents are still common occurrences.

Now, we have tried to place our library of information on incidents in a systematic arrangement. In fact, we use automatic data processing to tabulate and analyze the information. We have collected over 600 incidents to date and the number keeps growing.

Dr. Robert Taft, in his book, *Radium Lost and Found*, published in 1946, describes 180 incidents in which he was involved or associated—losses, thefts, ruptured sources, and so forth. He describes very vividly some of his early experiences trying to locate lost radium with the electroscope.

We recently had the opportunity to obtain the reports of a man who was associated with the radium industry from 1918. He has been personally involved in investigating 146 incidents in the Eastern States. I am sure many of you would be able to point out radium incidents which we are not aware of because they have not appeared in the literature. Therefore, what we have collected thus far may be only a starting point.

The first incident in the United States occurred in 1906 when Dr. Robert Abbe of New York reported the rupture of a 50-milligram radium glass source. The source ruptured when it was removed from an applicator. It literally exploded. This is the first report in the United States of an incident caused by pressure buildup. Dr. Abbe contacted the Curie Laboratories and learned they had reported two similar instances. This was 1906, and remember, the first radium came into this country about 1902. And so we might say that, from the very beginning, one of the characteristics inherent in radium—the pressure buildup—was identified.

The most recent incident occurred last Monday. This involved the loss of a 5-milligram medical source which was discarded into wastepaper. The wastepaper was then baled and sold to one of several papermills for reprocessing. There are now five State health departments around the country checking boxcars of baled wastepaper to find where this radium may have gone. This is not only of concern biologically, but the contaminated paper could end up in the photographic industry.

This loss occurred last Monday, so we now have a spectrum of incidents from 1906 to September 1964. We are collecting new incidents at the rate of about two a month from newspaper articles and from State health departments.

I would like to take a few minutes to review some of these, in order to give you a better appreciation of the variety of happenings that are associated with poor radium management.

For example, the British incident which occurred at the Nottingham General Hospital in 1949 was quite significant. A 25-milligram source ruptured as a result of sterilizing the source in boiling water. The end cap blew off the singly encapsulated source, and radium salts were dispersed around the building when the unattended water boiled dry.

This incident, although we do not have the cost figures, required demolition of a considerable portion of the building to remove the radium. I might just mention that decontamination is expensive, time consuming, and inconvenient.

Mr. Hugill, the other members of our staff, and I have had the opportunity to work with the Pennsylvania Department of Health on the decontamination of a private residence outside of Philadelphia. This project was completed on the 17th of last month. A total of approximately 4 man-years was spent on this job. This project was undertaken in order to develop a better understanding of the nature of radium contamination and the extent to which it can be attached and fixed on materials. Another objective was to study the uptake of this material by the people in the house who were exposed to the chronic

mishandling of radium which started around 1910 and probably terminated in 1945. We removed contaminated debris containing approximately 50 milligrams of radium and placed it in 170 55-gallon drums, for disposal in a commercial waste disposal site in New York. It cost over $50,000 to decontaminate this $15,000 house. Although much of the cost of this particular project was for the study and research aspects, the fact remains that decontamination is not a cheap or easy task.

An article in the literature [*Nucleonics*, vol. 11, pp. 45–47, 1953] describing the rupture of a 40-milligram glass source at the Naval Radiological Defense Laboratory in 1953 could attest to this. A single 40-milligram encapsulated source used for training purposes ruptured when it was dropped on the floor and stepped on. As stated in the article, 8 months of difficult work were required to decontaminate the building. The cost of the operation was kept to a few thousand dollars because most of the labor was done by military personnel.

Some of the more interesting accidents and incidents which we have information on have occurred at larger hospitals. In spite of the fact that these facilities have the more competent and better trained personnel, they are not exempt from the problem of radium incidents.

A hospital in Cincinnati was contaminated when a 12.5-milligram source ruptured. The article on this accident [*Amer. J. Roentgenol.*, vol. 77, pp. 511–523, 1957] describes graphically what happens when the radium is spread around by the technician's shoes and clothing. The fact that the incident was not immediately called to the attention of the individuals responsible, resulted in a considerable amount of material being tracked around the premises.

A similar incident at a large hospital was reported [*J. So. Med. Ass.*, vol. 52, pp. 952–957, 1959] where the cap of a 25-milligram source became disengaged from the body of the source. The cap of the singly encapsulated source was secured by a press fit, and an eye for sutures was located in the cap. Approximately 2.5 milligrams of radium were lost from the source when the cap became disengaged. Fortunately, proper procedures were initiated to alert personnel immediately after the accident. Air-conditioning systems were turned off, and rooms were sealed and closed, thus restricting the spread of contamination. The hospital was fortunate that the loss only amounted to $5,000 and a number of days of inconvenience.

The incidents that occur most frequently involve the loss of control of radium sources. I am sure that you have all read about, or been told of, the typical health physicist who had to survey the local sanitary fill in search for lost radium, inadvertently thrown out with the trash from the local hospital.

Another example: A package was left on the counter of a Chicago electronics store. Fortunately, the store also sold surplus radiation-detection instruments. During the course of demonstrating one of these to a customer, it was observed that the unattended package produced a response on the instrument. When the package was opened, it was found to contain approximately 70 milligrams of radium. The State health department was contacted and they in turn contacted the radium companies. One of the companies identified the sources—through the serial numbers—as the same sources that were stolen from a hospital in Ohio 6 months previously.

Another case involved a high school student who worked as an X-ray technician in a hospital in Texas. He was interested in doing science experiments, so he took a radium source home and broke it open to obtain the radioactive material for an experiment. He contaminated his home. The advice of an expert was required for decontamination.

A 200-milligram radium-beryllium neutron source, used for a well-logging operation in Texas, was lost from the back of a pickup truck while the source was in transit. The source was contained in a well-logging probe, several feet long and several inches in diameter. The probe and source were subsequently recovered from a junk dealer who had somehow acquired them. He turned them over to the authorities after a $250 reward was posted. In the meantime he had disassembled the probe, removed the radium source and put it in his desk drawer for safe keeping.

A 1-gram radium source was stolen from a railroad car outside of Trenton, N.J., in 1959. The source was being used for industrial radiography of heavy metal castings located on the railroad car. It was stolen by three children. The dose to the skin of one child was estimated to be 1,400 r, and the maximum total body exposure was 10 r. The children are still being followed medically.

These incidents help to illustrate the consequences when proper instrumentation or the services of a radiation consultant are not available. Without these, the lost source could result in serious exposure to unsuspecting individuals.

An incident in a California hospital illustrates how a serious incident can be prevented when detection instruments are available. A radium needle was dropped in the operating room. Immediately, the surgeon requested the services of the hospital radiological physicist who had the proper survey instruments. Not until the operating room was surveyed was it learned that the source had bounced into a fold in the drape around the patient and was lodged there out of sight. This kind of accident could have been tragic had not the services of the physicist and proper instruments been available.

Not all incidents involving radium reflect carelessness during the use of the source. In July 1959, four radium needles were stolen from a physician's private office. The needles were in a container inside a 600-pound office safe. The safe and the sources were removed from his office; and the sources were never recovered.

An incident which reflects inadequate respect for radium occurred in the office of a dermatologist. The source was stored in a lead pig, in which the plug was jammed. In an attempt to retrieve the source, he drilled into the pig. In so doing, he drilled a little too far and broke the source. The resulting contamination, fortunately, was confined to a newspaper which he had the foresight to spread around the area. However, the results of a radon breath examination and subsequent biomassay indicated that the dermatologist had received a body burden exactly equal to the maximum permissible level.

Another interesting case involved two physicians who operated a radium-leasing service. They had an inventory of 8 grams of radium in 189 sources, located in a rented office in a large metropolitan area. It was called to the attention of the health department that these two physicians were consistently receiving film badge exposures in excess of 100 milliroentgens per week. A subsequent survey revealed that this was the result of improperly stored radium. The dose rates in the adajacent offices were excessive, and in the office on the floor above readings of 9 milliroentgens per hour were observed. Proper shielding corrected the problem.

Another similar case involved a physician in private practice who had an inventory of 90 milligrams of radium without proper storage facilities. The material was surveyed and a reading of 10 milliroentgens per hour was detected in the adjacent office occupied by another physician.

Improper storage of radium is a chronic problem in our observations and in the observations of State health departments. Occasionally this is caused when the sources are kept in old storage containers. The designs of old storage containers do not meet the current recommended standards. The designs may have been adequate for what was considered acceptable in 1930, but they are not necessarily adequate for the standards of today.

I would like to add one more incident. I think this is a significant incident, not only because it occurred in July of this year, but also because it contains an important lesson. Three 10-milligram needles which were given to the radiologist at a 150-bed hospital in Georgia, were being refitted into a storage container. The radiologist was conscious of the fact that the storage container needed modification, and the sources were being fitted to go into some holes that were drilled in the source drawer. The needles were originally procured in 1921 and had not been leak-tested or checked. They were singly en-

capsulated radium bromide sources with no pedigree, and were believed to be 10-milligram sources.

During this fitting operation, the technician noticed one of the sources was in two pieces. The sources were returned to the storage container to await the arrival of the State health department.

As soon as the State health department personnel arrived they suspected there was a significant contamination problem. This was confirmed by a survey of the hospital. A decontamination operation ensued that lasted 4 weeks and engaged about 14 people before the facility was restored to a normal routine. Initially, the contamination had caused considerable inconvenience. The pharmacy, linen supply, maintenance shop, and X-ray suite were restricted for several days. Only after extensive surveying and decontamination was it possible to get these facilities back into operation.

The radiologist was extremely concerned, and rightly so since there were no funds available that could be used for the decontamination. The insurance company was called in, and they advised that the "nuclear exclusion clause" exempted their company from responsibility for decontamination. A course of action that might have been considered by the hospital was to bring a malpractice suit against the radiologist to reclaim the cost of decontamination, since the radiologist leased the X-ray and radium suite from the hospital. The hospital, of course, did not desire to do this. Fortunately, help from the State health department and the Public Health Service was available to bring the problem under control.

Perhaps the most dramatic example of the cost of a radium accident occurred at an industrial facility in Cincinnati. A 50-milligram radium calibration source ruptured during use. The contamination was so extensive that the building was abandoned. The damages resulting from this accident amounted to over $250,000.

Not all radium problems have consequences as dramatic as some of the illustrations just cited. More frequently the problems are manifested by examples of improper storage, handling, and posting, and by sources that leak radon—a possible precursor to a serious rupture.

The health department of one Eastern State conducted an inspection of 54 offices of physicians in private practice who used radium and found that 11 percent had one or more sources that were leaking radon or radium. Forty-four percent of the offices also had improper storage for the radium sources based on present standards. Caution signs were absent in all locations where the radium was stored. This may seem like a minor point, but many a theft or inadvertent exposure could have been prevented if the source storage area had the proper signs.

Similarly, the Kansas Health Department just completed a survey of some 50 radium users, 28 of whom are medical users. Fifty percent had leaking sources, 80 percent had inadequate storage, and 95 percent had no caution signs.

One of the Southern States has found in the initial inspection of 46 radium users that 25 percent had leaking sources and 100 percent had inadequate storage. In every case where there was no labeling, or inadequate labeling, the State health department provided signs on a voluntary basis so there was no indication of the percentage of discrepancy in posting.

The State of Kentucky survey results indicated 35 percent of 46 radium users had leaking sources, 10 percent had improper storage, and 54 percent had no labeling.

A rather detailed study is now being conducted of the institutional radium users in Georgia. Of the 18 hospital facilities that have been inspected, 4 had leaking sources, 12 had improper labeling, and 10 had inadequate storage. A similar detailed study in Jefferson County, Ala., found that of the 10 medical facilities in the county, 4 had source leakage.

This general pattern of frequency of source leakages is supported by the work of Mr. Robert Gallagher, who published a summary of his experience in leak testing sources [*Amer. J. Roentgenol.*, vol. 90, pp. 396–402, 1963]. He found that of 664 individual sources he checked, 37 were leaking radon gas or radium. As for institutional facilities, he found that 3 of the 4 hospitals surveyed had leaking tubes or cells in their inventory.

All of these experiences and observations emphasize that the inherent characteristics of radium can result in serious incidents and accidents causing unnecessary exposure, particularly when there is a failure in the application of proper handling procedures. This suggests that there is a need for radium management programs at the State and local level and a need for a greater awareness of the problem by the profession. I would now like to turn the discussion back to Dr. Scott.

DR. SCOTT: Now, I think the problem is open for your general discussion. Many of you are among the most expert users of radium and know a great deal about it. We are here to receive your advice, help, and suggestions.

DR. TER-POGOSSIAN: First of all, if I may, I should like to make one remark that may be pertinent to this discussion. This remark concerns the price of the radium. Mr. Villforth mentioned the fact that the cost of radium was somewhere between $16 and $20 per milligram. This is, of course, quite correct; but this is the asked price. The bid price for radium is much lower than that. We recently sold a certain

amount of our radium and we obtained somewhat less than $4 per milligram.

The second remark that I should like to make and which is pertinent to the radium that we had at the Mallinckrodt Institute of Radiology is the following: As Mr. Villforth mentioned, old radium sources are extremely hazardous for the reasons that are very well outlined in his presentation. Also, they are dangerous because of the fact that the encapsulation which is subjected to a very large amount of radiation is usually weakened. When we considered the problem of the hazards presented in our institution by a large amount of radium, we, of course, considered very seriously the reencapsulation of the radium. We reached the conclusion that, from a purely financial standpoint, this was not a very rational operation.

The reencapsulation of radium is a very costly operation. When it is carried out by a reliable company, it costs somewhere between $30 and $50 per source. It really doesn't matter how much radium is in the source—whether there is 1 milligram or 10 milligrams or more.

So, again, I should like to point out two factors: The first factor is that *old* sources—when I say "old sources," I am referring to radium sources which are older than approximately 5 to 6 years—should be reencapsulated because most of them leak. We found that ours, indeed, did leak a certain amount of radon.

The second factor is that the reencapsulation of these sources is costly. And it is, incidentally, a recurring problem. A source, in my opinion, should be reencapsulated, whether it leaks or not, at least as often as every 5 years. Perhaps I am being overly conservative about that but, in the light of the expense involved in decontaminating a hospital after spillage of radium, I don't think that this conservatism is unwarranted.

On the basis of these considerations in our institution a few years ago, we replaced all our radium stock by cobalt and very recently we sold our radium.

As I mentioned, we received very little money for this radium, and I should like to add that the area where this radium was kept is being decontaminated right now because a fair amount of radium has leaked from the radium safe in which these sources were kept.

MR. STARCHER: Last year at M. D. Anderson Hospital we treated 4th cases with radium. We use about 1 gram of radium each week, and have done so for 17 years. For a short period of time (1954–56), we also tried cobalt 60. Our experience with cobalt 60 was not too satisfactory. First of all, let me say that we have used a considerable number of radium tubes and needles for the last 17 years, and we haven't had an accident. Therefore, one can manipulate radium without accidents. Of course, since the beginning, we have had good

physicists and other expert assistance. We have had accidents with iridium and with cobalt, and we have had some hair-raising experiences with bits of iridium wire scattered around. So some of the incidents that Mr. Villforth mentioned can happen with any kind of radiation sources.

In 1954 we moved to our new hospital, and we had quite a surge in clinical material. It seemed reasonable to try cobalt instead of buying radium.

Being perhaps old-fashioned and thinking that I knew a little about the clinical use of gamma rays in gynecology, I didn't want to upset the applecart which was working pretty well and, therefore, had the cobalt sources made equal to the strength of the radium sources.

The identification of the cobalt 60 tube which is thinner and made of steel is not as evident as is a 25-, 15-, or 10-milligram radium tube. One should have some measure of concern that the proper source be at the proper place in the proper patient.

After a while (it is amazing how time goes by) the 25-milligram equivalent was no longer a 25. So we had to get some new sources. There was confusion in identifying the sources, and each one had to be passed in front of an electroscope. How many people will do that? How many people are equipped so that they are going to check what they are putting in the patient? We used cobalt 60 for 3 or 4 years, and it began to be such a headache that we went back to radium.

DR. TER-POGOSSIAN: Dr. Fletcher, I certainly agree that the sources should be properly identified, but is it not equally difficult to identify a radium source as a cobalt source?

DR. FLETCHER: The problem is that the identification system is not permanent, and the decay complicates the arrangement of sources for treatment.

When one considers the oral cavity, the irradiation of a lesion of the lateral border of the tongue or floor of the mouth must be done just right. To do that, one must have a good radioactive stock, not only of various linear intensities but also of various differential loadings — Indian clubs, dumbbell, and so forth.

Three years ago we started to get explicit calculations of radium patterns with the computers. We were able to calculate what we had done for the past 10 or 12 years. It became apparent that any time the dosage rate had been too high, there was a high incidence of necrosis.

We found out that the classical rules of distribution are not correct. In order not to give irradiation too fast one must have a very elaborate set of sources, not only of .80 and .40 or .5 and .25 milligram per centimeter, but Indian clubs and dumbbells. One can do it initially with cobalt 60, but the sources are not permanent and one cannot continually adjust for every case.

There is probably something very wrong with the regulations for the use of radium, but let's not lose sight of the patient. For the cancers highly curable by radium therapy—gynecological (cervix, fundus, vagina) and the oral cavity—radium is hard to beat. When it comes to the use of gamma-ray therapy for chest wall recurrences from breast cancer or diffuse neck cancer or lung cancer, there is no question that one is better off by using iridium. Years back when we didn't have iridium available for an implant of the chest wall, it could take anywhere from 100 to 150 milligrams of radium. The operators were getting as much as 700 or 800 milliroentgens of exposure.

We have given up radon seeds in favor of gold grains. The strength of gold grains is more dependable, and there are gadgets available to make implantations more geometrical.

So, Mr. Villforth, some of your stories are true. I would say a good many of those are surely a thing of the past, but they do point out the necessity of much more regulation of the use of radium. That's for **sure!**

Incidentally, historically, in 1930 in England, practically all of the radium was owned by the British Radium Commission which was a private organization, and they were loaning radium to hospitals. Within 10 years, they had completely weeded out the odd users. In fact, the British Radium Commission was primarily responsible for the split of radiotherapy from diagnostic radiology because they put out very rigid regulations for loaning radium.

DR. SCOTT: Now, Dr. Fletcher, let's just summarize in a few short sentences the main points you made. Number one, you think we still have to have radium; that this is a very important treatment device that is essential. And then your second point is that radium, because of the long half-life, affords an easier method of dose calculation and a more certain uniformity based upon past clinical experience. Now, the next point you made is that there should be some better methods for the control of the sources . . .

DR. FLETCHER: Absolutely.

DR. SCOTT: . . . so that they have means of checking their leakage, and adequate storage with proper barriers, and so forth.

DR. FLETCHER: That's right.

DR. SCOTT: And registration of the sources.

DR. FLETCHER: And facilities to handle radium sources.

DR. SCOTT: And facilities for doing it, that this is the major deficiency in the proper utilization of radium today. Is that correct?

DR. FLETCHER: Yes, sir. Not guaranteeing the clinical inexperience of the users; but that is something else.

DR. SCOTT: Then that would be your last point, that there should be some method for identifying the capability of the user.

DR. FLETCHER: That's true.

DR. TOUCH: Dr. Scott, I don't think Dr. Fletcher really meant to imply there are no other nuclides that could be substituted from the standpoint of half-life because I think cesium, for instance, doesn't have the objection that cobalt does.

DR. FLETCHER: I would say that those clinicians who would like to use radium for a clinical situation should not be put in the position that radium is no longer available. Those who wish to keep on using radium should prove they have the facilities to use it without danger or a minimum of danger.

I would again like to be on the record as stating that, outside of the oral cavity and gynecology, the other gamma-isotope substitutes are superior to radium, and there is a great place for them.

DISCUSSION ON CONCLUSIONS

Conclusion Number 1

1. All naturally occurring radionuclides, including radium, radon, mesothorium, and so forth, as well as accelerator-produced radionuclides, should be subject to the same radiation protection regulations as are reactor-produced radionuclides.

In Discussion:

MR. VILLFORTH: Through the licensing activities of the Atomic Energy Commission's regulatory program for "byproduct material," there is a review to see that the applicant's storage and handling equipment are adequate for the material being handled. Thus, there is minimal exposure to technicians, nurses, and others from the use of "byproduct material" in medicine.

Concerning radium sealed sources, there haven't been any controls on the manufacture or reencapsulation of radium sources. There are many old radium sources still in use—many of these 25 to 40 years old—which haven't been leak-tested. There is a need for standards and uniform regulations on leak-testing. Also, there is very little information available to assist State regulatory agencies to determine the adequacy of sources based on their design. Many of the older sources, such as those with soluble radium salts, friction fitted plugs, single encapsulation, and so forth, should not be used since they have a greater potential for rupture.

DR. HANS: Dr. Lough, does the AEC have control of cyclotron-produced isotopes?

DR. LOUGH: No, sir. At one time we had a program, auxiliary to nuclear reactor-produced isotopes, which involved the distribution of certain radioisotopes that could be produced better by cyclotron than in nuclear reactors.

When an isotope applicant obtained a cyclotron-produced isotope under this program, he procured what was then called an authorization and is today called a license. He was obligated to meet the same conditions of safety and also offer assurance that safety would be maintained as he would have had he received a reactor-produced isotope. But, on the other hand, this fellow who wanted a radioactive material could also go to a cyclotron operator and say, "For $35 an

hour of cyclotron time, could you prepare me so much magnesium 54?"; and he could get it. If he didn't get it through the AEC, he got it privately.

For example, tantalum 73, which is used in brain tumor work, is a cyclotron-produced isotope and is not under license.

MR. HERMAN: There are now, interestingly enough, about 65 cyclotron isotopes routinely available throughout the world. The AEC some years ago withdrew from the production of cyclotron isotopes. However, the AEC, for all practical purposes, still has the only machine on which the irradiations can be done to satisfy production needs, so we do all the irradiations.

The private groups in the country take these irradiated targets, separate the appropriate nuclides, and package and distribute them.

In addition, a large percentage of the cyclotron isotopes used in the United States comes from abroad. So for all practical purposes, cyclotron isotopes are not under the regulatory control of the Commission and haven't been for a long time.

DR. HENSHAW: Besides radium, two other natural radioisotopes, namely, radon and mesothorium, which are not controlled by the Atomic Energy Commission, should also be considered in the formulation of protection regulation. Radon is used quite extensively in medical practice. [This subject was discussed further in the section on conclusion 8.]

Conclusion Number 8

Because of the special contamination hazards associated with radium, due to its physical and chemical properties, minimum standards of source design, construction, and testing should be established for this radionuclide by a body of appropriate experts.

In Discussion:

DR. SCOTT: Mr. Villforth, in your routine testing of radium sources, what was the percent that showed leakage?

Also, I would like to ask how many of these sources that you checked had ever been checked before for leakage. What is the custom in this country? My impression is that nobody checks them until there is some accident.

MR. VILLFORTH: The information I quoted was not based on my personal experience, but rather on the observations of others. They did not always include this information, because in most cases the pedigree, or history, of the source was not available.

The best answer to your question on the frequency of leakage is reported in Mr. Gallagher's work [*Amer. J. Roentgenol.* vol. 90, pp. 396–409, 1963]. He implies approximately 5 percent of all sources he checked—and that's based on some 600 observations—showed leakage. However, when you look at this in terms of facilities, somewhere between 50 and 75 percent of the facilities had a leaking source or sources in their inventory.

DR. MORAN: In Manchester, England, leaks were very infrequent. Needles were checked and sent back for reloading more often because they were scratched or bent.

I also believe periodic leak-testing should be performed every 6 months. I don't think that we should make a blanket statement about reencapsulation of radium that is not leaking.

DR. FLETCHER: If a source is leaking radon, it is a warning that it will go bad, and I think that it should be reencapsulated. But if a source is not leaking, and it has proper standards of encapsulation, I don't think we should require periodic reencapsulation.

DR. LOCHE: In the Atomic Energy Commission this business of testing sealed sources, the need for it, and the frequency with which it should be done, has proved to be an evolutionary matter. The regulatory side of the AEC at present and in the recent past is attempting

to increase the interval between required testing of sealed sources because specifications for the design of the sources have been developed and experience has shown that testing is not needed so frequently. But these things have to go hand in hand.

I think that this will evolve. You test sources frequently because you are afraid they may leak, and then you find they don't leak. You have proven your case. Your construction is good. All sealed sources used to be leak-tested every 6 months. In the case of some sources, at least, this is now relaxed, and the interval between leak-tests may be longer under the AEC regulations.

Leak-testing was quite expensive for industrial sources. They had to hire qualified radiological physicists to come in on a consultant fee basis to take a piece of filter paper and swipe the thickness gages. It proved not to be necessary—the source didn't leak—but it had to be done under the regulations.

MR. HENSCHKE: In formulating standards for sealed sources, consideration should also be given to cobalt 60, iridium 192, and tantalum 182 sources, which have been encapsulated before neutron activation. Preencapsulation results in a great saving in cost. We have used successfully for many years sources preencapsulated in stainless steel, aluminum, and copper.

DR. SCOTT: Of course, we couldn't set these standards in this group, certainly not at this time even if we thought of doing it. But who would be the logical group to do this? Where should this be done?

MR. VILLFORTH: The State health departments want to know what is good and what is bad in terms of source design. For example, if you were in a position to approve or disapprove an application for a radium license from a physician who has glass encapsulated radium, would you approve it? This is the kind of question the States are going to be faced with.

DR. MORGAN: It is difficult to conceive the chaos that would exist in this country if 50 States had 50 different sets of regulations. Hence, it is very important that these States have available a responsible group to whom they can turn to get usage, and technical and source standards.

DR. SCHULZ: Can someone tell us what the present status is of various States with regard to registration of radiation sources? Are we soon going to be in a position where all sources of radiation (including, of course, radium) are going to have to be registered with some agency?

MR. VILLFORTH: At present 38 States require registration or licensing of radiation sources. In addition there are now eight States that have assumed the responsibility for the control of "agreement material" from the Atomic Energy Commission. They constitute about one-third of the population of the United States. It looks like

within the next year or so they will pass the 50-percent mark. And probably this will level off at 80 or 90 percent. The eight States that are agreement States have incorporated into their rules and regulations the procedures for controlling radium. I think all but two of these States license radium. The other two require registration. Several other States are active in radium management programs and, through general authority, are involved in inspection and educational programs.

DR. MORGAN: How many States with X-ray sources have regulations now?

DR. PIERCE: There are 38 States that have some jurisdiction over sources of radiation and ask registration information. Some of them go beyond that to inspection and compliance, but all of them ask persons who own sources or acquire new sources to report the fact to the health department.

DR. MORGAN: And I think it is quite important that not only should the States have nationwide uniform regulations, but also that these regulations, particularly as far as source characteristics are concerned, be based on a performance standard of some sort and not just on registration.

DR. HERMAN: Of course, we haven't known at all about the industrial side of the picture; and I think it is just as well, since I think radium is for all practical purposes disappearing from industrial applications at an ever-increasing rate.

Fortuitously, relatively inexpensive substitutes for radium—artificial nuclides—were made available in rather large quantities. The very same thing may take place in the medical profession.

Perhaps, however, the reason that it has taken place in industry is that there was a large research and development effort in substitutes for radium.

DR. TOCUS: I think that the group today is approaching gingerly, and probably quite wisely so, the conclusion with regard to mode of action. This is always the most difficult step to take, of course. Dr. Morgan referred to one point which should be kept in mind at this juncture because it is a timely problem—namely, that if some order is not established (a standard type of procedure which could be subscribed to, at least if States elected to do so) there will be tremendous chaos.

I am sure you are familiar with the fact that the Atomic Energy Act does not embrace any control over radium, but that the State regulatory bodies operationally are frequently including radium in their basic legislation and their regulations. The need is, therefore, for an acceptable set of standards, technical standards, for the design of the sources and perhaps for the use. Unless there is a set of tech-

nical standards for the fabrication of the sources, with, perhaps, some alternatives included in the basic statement, there will be chaos because the States will grasp at sets of standards which they think will meet the issue. And these will vary from State to State much more widely than if there were a basic document drawn up by a set of experts, such as are represented here today, to which the States could look for sound guidance and perhaps even accept bodily.

This is not only of importance from the regulatory standpoint, but it is also important from the industrial standpoint, because the manufacturers are panic-stricken at the prospect that they will develop a line of merchandise which is acceptable in New York and not in Pennsylvania because of lack of uniformity from one State to the next. This should not be overlooked.

MR. WILKINSON: The State regulations that pertain to radium are basically the same as the regulations that pertain to AEC licensed material. They involve "common sense" radiological health procedures.

Now, a specific question has come up regarding the integrity of the sealed source. I doubt if the standards that will be developed to improve the integrity will ever become a part of State regulations.

This is analogous to AEC licensed material. The Atomic Energy Commission collects data on various makes, models, and designs of sealed sources. From the analysis of this data and from incident reports from licensees, they are able to preempt a possible ruptured or leaking source.

In addition, there is a program at the Isotopes Development Center, Oak Ridge National Laboratory, where these sources are subjected to a variety of stringent tests. Cobalt 60 needles, for example, are exposed to autoclave tests. They are bent, dropped, and exposed to other tests to see if they maintain their integrity under the extremes to be expected during their use.

Therefore, the experience collected from the users, plus the data obtained from the testing program conducted at the Oak Ridge National Laboratory, are brought together into a report that can be used as a guide in licensing users of these particular sealed sources.

Then, when a State assumes the responsibility from AEC to control these materials, it is provided with this up-to-date information. The State health department reviewer can then refer to this information to find if the make and model number of that source listed on the application is or is not satisfactory. This information is considered in the awarding of a license.

Now, what is missing is information available from a similar program on radium sources.

Unfortunately, we have no way of retrieving detailed experience

on the use of radium sources during the past 40 years. This is partly why we set up a system to collect and evaluate information on radium accidents and incidents. Hopefully, this will enable us to evaluate a particular type of source and see if it has a potential for failure. These evaluations, coupled with a system of source-testing, can serve as a basis for guides or standards.

The States need guides for sealed radium sources and they need them now. These guides may be published as formal standards or they may be in the form of a report based on the experience of a group of experts such as this.

MR. SCHULZ: Most standards in this country are from the American Standards Association, aren't they, with some fashion of advisory help? The manufacturers customarily work with this group.

MR. BERMAN: The American Standards Association does have a functioning subcommittee now on sealed sources of radiation. The principal impetus for these proposed standards they are developing is related to sealed source safety rather than professional use of the sealed sources. But there is a functioning group right now within ASA doing just this.

MR. TAYLOR: I was secretary of this subcommittee on sealed sources standards for the ASA for several years. They are doing a noble job to set up standards which can be subscribed to by the industry and will maintain safety from the standpoint of the integrity of the source under the conditions that the sources are to be used.

I really believe, however, that this project we are talking about today is of an extremely specialized nature; that the most outstanding talent that can be brought to bear on it is not from the industry, but from the professional users who are already thoroughly conversant with the characteristics of the existing equipment in the form of needles available for use; that these needles by and large do maintain their integrity and have gone through the fire of years of test and modification and design. If the British standards are generally quite satisfactory, that might be a springboard from which one could take off.

I think it would be far more practical and more productive in a short period of time if an *ad hoc* group could develop the set of standards and hand them as a package to the ASA, because the committees of the ASA are made up primarily of industrial members. So I would be distressed if this were turned over for solution to the ASA without previous work by a professional group.

MR. SCOTT: I certainly agree with you because it takes the people who are the actual users to say what they want and how it should be and then let the ASA committee formulate the true specifications.

MR. TAYLOR: If the *ad hoc* group comes up with recommendations for

sources which will not maintain their integrity, then somebody else has to do something about this and modify it and reconcile these differences. But I don't think the AMA should start. I think professional groups should make the start.

DR. PIERCE: Could I ask a question of Dr. Boland? There must have been some set of circumstances, force, or motivation behind the creation of the Radium Commission in the United Kingdom. It must have been more than an accident.

DR. BOLAND: I am not quite sure. It was before my time, but I believe the purpose was to buy radium and to loan it to hospitals at a time when it was in very short supply.

DR. FLEMMING: It was the late twenties—'28 or '29. Historically, in 1925 radiotherapy was not well established, but England was way behind France and Germany and Sweden. And 10 years later they were far ahead.

DR. PIERCE: They set the standards?

DR. FLEMMING: They did what we are talking about today—set requirements for protection in the use of radium. They started with simple protection methods without telling the people, "You don't know what you are doing; you don't know how to use it clinically."

MR. VILLFORTH: I just wanted to emphasize that the demand for these standards is very acute.

DR. FLEMMING: I don't think there is any argument about that. I would suggest that you appoint a committee. The M. D. Anderson Hospital is a very large user of radium and, therefore, has procedures and requirements that they use all the time. We would be glad to be host to a group from the State health departments to go over the actual procedures we are using.

MR. VILLFORTH: There are still 1,700 users in private practice. How do we impose the elaborate M. D. Anderson Hospital procedures upon them?

DR. FLETCHER: We would have to soften it up a little bit.

MR. HERMAN: Now, I would like to pose a question, if I may, because I think it gets involved in this question of regulation. It certainly has been our experience that, in terms of regulation of the use of isotopes, there has been a perfectly normal and natural reluctance on the part of the Atomic Energy Commission or other regulatory groups to over-regulate, if you will, the medical profession because of certain unique characteristics of radioisotope users in the medical profession as opposed to industry.

And I wonder whether some of your suggestions, Dr. Fletcher, would be considered by the American Medical Association, which tends to look at these 1,700 general practitioners that we have talked

about as opposed to a relatively smaller group of specialists in the field.

DR. FLETCHER: I don't doubt they will look at the general practitioner's standpoint.

DR. MORGAN: There has been a reluctance, though, to differentiate between the well-trained and the average man.

DR. LEWIS: On of the approaches in handling this would be by an educational program, through the organizations represented here such as my own group, using a textbook and other information sources. We can carry back the same sort of summary Mr. Villforth provided to the organizations which we represent and provide this in our monthly publication and carry on a campaign, pushing the subject by an educational program.

One way of pushing, beside the one you mentioned, is by State regulation. You can do it from two sides, both State regulation and educational programs carried on by the organizations represented here today.

DR. FLETCHER: I think a handbook should be sponsored.

DR. ARNESON: May I add one point? For example, there is a manual of standards that applies to obstetrical and gynecological departments. This manual of standards was developed by the College of Obstetricians and Gynecologists and includes a section that deals with radiation protection and the use of radiation. So, at least, these should be avenues through which some of these things might eventually go, because I think we have in those organizations mechanisms that would apply the information gathered here.

DR. CHADWICK: In following up on what Dr. Arneson said, I wonder whether the mechanism shouldn't be to go from this group, which represents a rather broad spectrum of organizations, back to the few professional organizations that might be the most appropriate ones to develop and disseminate such standards, with the offer of whatever help this group (or people that this group might draw on) could supply.

DR. MORGAN: There are two sets of standards that have been discussed here. There are professional standards which I think quite appropriately fall within the purview of the professional societies. The College of Surgeons, for example, has done a magnificent job in raising the standards of surgical practice. It seems quite appropriate that a similar method be followed for the professional standards of radiology.

Then there is a group of technical standards, e.g., standards of source design. Here, it seems to me, the British have done very well, and perhaps we need to follow their example. The formulation of technical standards is difficult to do through scientific and professional

societies. One may expect such societies to provide valuable consultation as they did in Great Britain, but somewhere there is needed an organization devoted primarily to the formulation and promulgation of workable and effective standards. I would raise the question as to whether or not the Public Health Service is an appropriate place for this responsibility to reside, with the input of information coming from the professional societies represented around this table. Such a move seems quite logical; the medical profession respects the Service. On the protective side, public health is the responsibility of the State health departments, and the Public Health Service is the group to which these departments turn when problems arise.

DR. SCHULZ: I would like to say the thing we are talking about right now, quite apart from professional standards and use standards, is manufacturing standards. I wanted to ask Dr. Morgan whether or not the Public Health Service is, in fact, concerned with manufacturing standards, or if this is not more appropriately deal with by some mechanism or machinery of the ASA activity, which is already engaged in this activity with proper advice and consultation.

DR. MORGAN: Perhaps I should let Dr. Chadwick answer that since he represents the Public Health Service and I do not. I can only say this: In the X-ray field, the Division has established a very keen interest in not only the usage standards, but also in manufacturing standards as well. Indeed, it has established a number of subcommittees of experts, who are providing the Division with substantial guidance on problems of this sort.

DR. SCHULZ: Isn't that primarily concerned with safety and protection and not with regard to dimensions and strengths?

Dr. Chadwick, you might like to continue.

DR. CHADWICK: Well, I am interested primarily to hear what the various people here feel is the appropriate group to do it. We are interested in seeing that the job gets done. We are interested also in seeing whatever useful role we can play. And if the group feels in general that the American Standards Association would be the appropriate group to come up with standards of this sort—i.e., the measurements, dimensions, and so on, of various radium needles—we would be prepared to do whatever we could to support that effort.

DR. MORGAN: It seems to me that among the several problems discussed here, there are two which stand out. One is a set of problems which pertains to radiation sources and their control; and the other pertains to the professional usage of various radionuclides.

The first constitutes an immediate problem for the Public Health Service because a number of State health agencies are asking guidance from the Service on radium source legislation.

John Villforth's discussion is largely the outcome of this. States are rapidly moving toward the development of codes of source control. And it is rather important that these codes exhibit a degree of uniformity, nationwide, if confusion is to be avoided.

Since the Division of Radiological Health is the place to which the States turn for this guidance, I think it would be wise for the Public Health Service to establish a subcommittee, associated with the Division of Radiological Health, which would address itself to the problems of radionuclide source control. This subcommittee should use the advice and counsel of established groups which are concerned with radiation protection problems—namely, the NCRP, and certain government agencies, and the societies represented here. Out of this committee might be formulated a set of rules, if not standards, which the Public Health Service might provide State health agencies for use in the formulation of legislation on radium source control.

As far as the problems of professional usage go, I don't know what the possibilities are for better professional standards, but it might be well for the societies which are represented here to start looking at the methods used by the American College of Surgeons in raising the standards of surgical practice in years gone by. The problems faced by radiology today are quite similar to those encountered by the ACS several years ago.

Conclusion Number 5

A suitable substitute for radium, with less contamination hazard is desirable. Because of the large body of clinical experience accumulated with radium, substitute sources should be made available which conform to the dimensions and dose distribution patterns of existing radium sources. Cesium 137 sources seem capable of satisfying these requirements. For temporary interstitial treatments where flexibility and shielding are important considerations, iridium 192 is the isotope of choice at the present time. For permanent implantation, gold 198 is a suitable substitute for radon. The use of radium plaques should be discontinued; strontium 90 plaques are a suitable substitute.

In Discussion:

DR. HENSCHKE: In the last 12 years, we have been carrying out a great deal of developmental and clinical work in an attempt to find better radioisotopes than radium and radon. In discussing the pros and cons of various radioisotopes, one must distinguish between removable applications, such as radium needle interstitial implants, intracavitary applicators, surface molds, and so forth, in which the sources are removed from the patient at the end of the treatment, and permanent interstitial implants, such as radon seed implants, in which the sources are left in the patient permanently.

This table shows the radioisotopes which are in clinical use for removable applications.

Radionuclide	Half-life	Half-value layer (inches)
Radium 226	1,600 years	½ Pb
Cesium 137	27 years	½ Pb
Cobalt 60	5.3 years	½ Pb
Tantalum 182	115 days	½ Pb
Iridium 192	75 days	1/16 Pb

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For an evaluation of these radioisotopes, it is useful to try to formulate the properties of the ideal radioisotope for removable applications. In my opinion, these are in order of importance:

(1) *Low gamma energy* to improve radiation protection. Cesium 137 with its monochromatic radiation of 660 Kev. and iridium 192 with its average energy of approximately 380 Kev. are in this respect preferable to radium 226, cobalt 60, and tantalum 182, which have such high gamma energies that their half-value layer in lead is approximately one-half inch. At energies as low as 300 Kev., no problems exist for clinical dosimetry, since the dose distribution in tissue up to 6 centimeters is practically the same for all these radioisotopes.

(2) *Long half-life.* By far the best in this respect is radium, which has such a long half-life that no dose adjustments for decay are necessary and no replacement would be required. The long half-life is the main attraction of radium, beside the fact that until recently it was not subject to regulatory control. Next best in this respect is cesium 137. Cobalt 60 produces considerable problems in practical use due to its decay, and this easily leads to practical errors. Iridium 192 has such a short half-life that daily dose adjustments are required.

(3) *Safety in case of capsule breakage.* In this respect, radium is by far the worst. Breakage of radium capsules has required many costly and embarrassing cleanup operations. The special danger of radium lies in the fact that radium is a powder, which is easily spread around, and that it has a very strong alpha radiation. This alpha radiation is of no use for intracavitary or interstitial therapy, but it makes radium by many magnitudes more dangerous than a comparable gamma emitter which does not emit alpha particles. Much better than radium is cesium 137, which does not emit alpha particles. Cesium 137 is today also available, incorporated in ceramic so that it does not spread around as easily as radium. The greatest safety in case of capsule breakage is afforded by cobalt 60, iridium 192, and tantalum 182. These isotopes usually are used as solid metal cylinders, which remain intact even if the capsule breaks. In all of our cobalt 60 sources for interstitial and intracavitary therapy, we have not used pure cobalt, which rusts and flakes easily, but one of the resistant cobalt alloys, such as Haynes No. 25 alloy.

(4) *Production by neutron capture.* Cobalt 60, iridium 192, and tantalum 182 are produced in this way. It is, in general, the least expensive way to produce radioisotopes for removable applications, especially since it is possible to encapsulate radioisotopes which are produced by neutron capture before activation. Preencapsulation brings a great saving in the cost of the production of the sources since all mechanical work can be done with inactive material. In con-

trast, the filling of capsules and needles with radium or cesium 137 which is produced by chemical extraction is a dangerous, complicated and, therefore, costly procedure.

(5) *High neutron cross section* for radioisotopes produced by neutron capture. This permits production of radioisotope sources in very small sizes, which is particularly important for afterloading techniques. It also decreases the costs of activation. Iridium is especially good in this respect, having a cross section of approximately 750 barns while cobalt has a cross section of only 34 barns. To produce a cobalt 60 source of the same size and activity as an iridium 192 source, activation times approximately 30 times longer are necessary at the same flux.

(6) *Low beta energy.* Most of the artificial radioisotopes are quite satisfactory in this respect, since their beta radiation is largely filtered out by the wall thicknesses necessary for mechanical stability. Particularly troublesome in this respect are radium and radon, which require a wall thickness of 0.5 millimeter platinum for satisfactory elimination of the primary betas. This is a special disadvantage for needles for implants. Radium needles, for this reason, have a rather large diameter of at least 1.6 millimeters.

As is apparent from this discussion, there simply is not a radioisotope which is ideal in every respect. Which isotope is best will depend largely on the particular needs of the physician or of the institution. For the small-scale user who is competent and careful, radium capsules and radium needles can be satisfactory. Cesium 137 appears as the first choice as a replacement for radium because it is safer than radium in case of breakage, does not need reencapsulation, is cheaper, and is easier to shield. Cobalt and iridium are still much safer and also cheaper to produce than radium, but their short half-lives present many problems in practical use. They are, however, the first choice for afterloading techniques.

The conference of the International Atomic Energy Agency in Vienna, November 1963 (at which Dr. Shalek from the M. D. Anderson Hospital was also present as a delegate from the United States, besides myself) also came to the conclusion that, for institutions which acquire a new stock of radioactive needles and capsules, cesium 137 is preferable in place of radium for conventional techniques, while for afterloading techniques iridium 192 and cobalt 60 will usually be the first choice.

MR. HOLAND: What about including tantalum with iridium as a substitute? Others have developed tantalum as a flexible source.

MR. HENSCHKE: Iridium 192 is preferable for all applications in which tantalum is used. The reason why tantalum was used originally was that at this time iridium was not available in the form of such a

fine wire as tantalum. We surmounted this difficulty by using an alloy of 30 percent iridium and 70 percent platinum, which can be produced in extremely fine wires, and introduced iridium 192 in this form for intracavitary and interstitial application in 1959. Compared with tantalum, iridium has two important advantages:

(1) Its gamma energy is much lower so that protection is much easier.

(2) The neutron cross section is much higher and it can, therefore, be produced at less cost or in smaller diameter.

The conference of the IAEC in Vienna, November 1963, "Physical Aspects of Interstitial, Intracavitary, and Surface Therapy Using Sealed Radioisotopes," also came forward with a clear-cut recommendation that iridium 192 should be used in preference to tantalum 182.

DR. FLETCHER: Iridium is excellent for afterloading and protection when you are doing implants. When you get a patient requiring a lot of radioactive material in his chest wall, it is much easier to protect nursing personnel and visitors from iridium implants than from any other.

DR. SCOTT: I was just trying to review Dr. Henschke's suggestion. As I understand it, this International Conference recommended that in the future you buy only cesium.

DR. HENSCHKE: Yes, for conventional type sources for temporary intracavitary and interstitial applications. For most afterloading techniques, however, iridium 192 or cobalt 60 are preferable.

DR. SCOTT: If you have radium, you keep radium and keep it under proper control. And then, if I understand Gilbert Fletcher correctly, he says that he would agree to having cesium similar to his radium. Is this correct, Gilbert?

DR. FLETCHER: I think cesium would be fine because it decays so slowly. You can count on it for a long time.

DR. TER-POGOSSIAN: I should like to point out another advantage of cesium needles over the radium needles. This is the spectral distribution of the radiation emitted. Cesium emits a single monochromatic gamma line at around 660 kilovolts, whereas radium has a wide spectrum of radiation which is undesirable from the therapeutic standpoint.

DR. HENSCHKE: It is true that dosimetry for monochromatic gamma emitters, such as cesium 137 and cobalt 60, presents fewer problems than that for gamma emitters with a complex gamma spectrum, such as radium 226 and iridium 192. For the clinical practice, however, where an accuracy of ±10 percent is quite satisfactory, the complex spectra of radium and iridium are not objectionable.

DR. RAVENTOS: I would like to ask whether these isotopes are all that

are available to us. Out of all those nuclides in the book, isn't there anything else that could be considered? And if we do a little research on it—consider making alloys—would there be any other sources?

MR. HENSCHKE: For temporary implants one could consider low-energy gamma emitters, such as thulium 170 and iodine 125 and other similar radioisotopes which have been developed and are used for industrial radiography at low energies. This would simplify the protection problem greatly. Unfortunately, no gamma emitter with low energy is available which has a long half-life. For permanent interstitial implants, a number of interesting radioisotopes in the low energy range are available. We are presently engaged in studies with xenon 133 (half-life 5.3 days), cesium 131 (half-life 9.8 days) and iodine 125 (half-life 60 days). All of these have their main lines around 30 Kev., which permits complete protection with very thin metal foils.

DR. SCOTT: Now, we have gentlemen here from AEC who might have some views on this or suggestions as to possible other radionuclides or new forms for the old ones.

Dr. Lough, would you care to comment on this?

DR. LOUGH: Dr. Scott, at one time I think I might have been willing, but I have been out of touch with the development of uses of radioisotopes for about 8 years now. And I think Mr. Berman who is in this field might be qualified better to discuss that phase.

MR. BERMAN: Let me just suggest one. I can't talk from the medical applicability of the isotope, but people who are producing the material suggest the yttrium beads being produced by the Brookhaven National Laboratory, which have been used to date essentially for experimental purposes. Yttrium 90 beads are now routinely available from Brookhaven. They have very much the same characteristics—perhaps not the specific activity—that I would imagine iridium 192 has.

One of the nice things, if you want to look far ahead and where you are terribly concerned about the half-life of your material, is the milking technique where the parent radioactive material is relatively long-lived, and the daughter product which you want is relatively short-lived. One can periodically remove the daughter product from the generator on demand.

DR. SCOTT: What substances are these?

MR. BERMAN: Well, yttrium 90 is one. Some of the iodine isotopes are also routinely available to milkers.

DR. HENSCHKE: Yttrium 90 has a half-life of 2.4 days and has been used as a permanent implant, especially for destruction of the pituitary. It is the most suitable beta emitter for this purpose because it has a very high energy of 2.18 Mev. In cancer therapy, however, we are not aiming for destruction, as in the special case of the pituitary ablation.

but for selective effect on the cancer cells. For this, in my opinion, gamma emitters are preferable to beta emitters.

DR. TER-POGOSSIAN: Dr. Henschke, if I understand you correctly, on the basis of this table radium really has absolutely no advantage over cesium.

DR. HENSCHKE: The only advantage which radium has over cesium is the longer half-life, which permits use without correction for decay. If somebody uses radiation only rarely, and if he already has a stock of radium sources, I think that he should not be forced to use cesium; but for a new department, cesium is recommended.

DR. TER-POGOSSIAN: Should an individual who uses radiation so seldom use radiation at all?

DR. HENSCHKE: Even some large departments use intracavitary and interstitial implantation infrequently.

DR. TER-POGOSSIAN: My question still stands.

DR. FLETCHER: No more than an occasional surgeon should do surgery. You can have a gastrectomy done by somebody who does a gastrectomy every 5 years—that may be kind of dangerous.

There is one point I want to bring out. There is a certain amount of simple clinical experience in finite details that has been acquired with radium.

This is why, personally, I am sticking to radium when it comes to the exquisitely curable implant of the oral cavity. And when you are going to do one on the floor of the mouth—and we have done quite a few—it becomes complicated. It is so close to bone that the mucous membrane is very fragile, and you must minimize your points of overdosage; otherwise, you get necrosis.

This is a clinical matter. If others want to use something else, that's all right. But if you are going to duplicate radium, it is not easy to do.

There is a great deal of simple clinical experience, perhaps pedestrian, and clinical considerations must not be forgotten in that drive to eliminate something or other because something else looks nice. And it does look nice, but let's not forget the clinical experience.

DR. TER-POGOSSIAN: Yes, Dr. Fletcher. I certainly agree with that. But this exquisite experience applies to one set of needles because if you compare radium needles from one institution to another, you will find different thicknesses, different dead ends.

DR. FLETCHER: That is not true.

DR. TER-POGOSSIAN: Certainly they are not standardized.

DR. FLETCHER: There is more and more general use of the British standards or the British stock. For instance, if you set up a radiotherapy center you can buy the stock which we have used here, and you can duplicate pretty easily what we have done.

DR. TER-POGOSSIAN: Certainly.

DR. FLETCHER: So it is applicable.

DR. TER-POGOSSIAN: It is reproducible.

DR. FLETCHER: It is reproducible.

DR. TER-POGOSSIAN: But as it stands now, it varies from one institution to another.

DR. FLETCHER: My experience is with the British stock of needles.

DR. CHADWICK: I am interested in this recommendation that henceforth the new institutions or new users or new installations be supplied with cesium rather than radium. But the institutions that currently have a large supply of radium continue to use radium. Is there a problem here of the training of people who are coming along? In other words, if all of the existing institutions where the large volume of training of the radiotherapists is done continue to use radium, is it practicable to think that new radiotherapists would then go to an institution and use cesium rather than radium?

DR. HERCHER: Radium needles vary relatively little in size, since they cannot be manufactured in diameters under 1.6 millimeters and since, on the other hand, larger diameters would not be desirable. In contrast, cesium and cobalt needles are manufactured in many different diameters.

I believe that the manufacturers should be encouraged to produce cesium needles in exactly the same diameter as radium needles and to make the active length a little shorter than for radium needles so that the cesium needles would, in effect, duplicate the standard radium needles. In this way, one would have the assurance that the clinical effect would be the same, and someone trained with radium needles could switch to the cesium needles without difficulty.

DR. SCOTT: This is a very important thing. I can see the great value of having a clinical precedent established in your mind, where you know from experience just what a particular setup of needles will do and you can observe this over the years. You know the kind of reaction you are going to get. And you know how you can reproduce this. This kind of experience cannot be gained by switching from one to the other.

DR. FLETCHER: Mr. Chairman, I didn't mean to be against using new things. Perhaps I am purposely taking a conservative stand. As I said originally, one should not be stampeded into all sorts of things and forget the patient. Let's not forget the management of that part of the tongue or floor of the mouth that should be done just right. Let's try to do what we can for protection, but let's not forget the patient.

DR. SCOTT: Yes, there is a very close area here between what is therapeutic and what is damaging.

DR. FLETCHER: Right.

DR. CHADWICK: Dr. Heuschke, I would like to restate what you said in my own words to make certain I understand it. What you are suggesting is that there ought to be a move to encourage the manufacturers and processors of cesium applicators to follow design characteristics so they will be interchangeable with the well-established and more or less standardized applicators, radium needles, and so on. Is that right?

DR. HEUSCHKE: Yes.

DR. CHADWICK: And you say this is currently not the case.

DR. HEUSCHKE: Cesium and cobalt needles are manufactured in diameters thinner than radium needles. Thinner diameters might be better, clinically, since they produce less trauma. However, in order to transfer the large clinical experience gained with radium needles, cesium needles should be available in exactly the same diameter and isodose pattern as radium needles.

DR. LOCHE: I think this last point is an extremely important one. I don't think that the prospect is hopeless of getting this desired result. In the very recent past, a group of instrument users in the major laboratories of the Atomic Energy Commission became dismayed because, when they wanted to lend components to go into a large array of instrumentation, they found that one manufacturer made his components 10 centimeters wide and another made them 10.5 centimeters wide, presumably to do the same thing, but with perhaps some variation in internal design and, therefore, performance.

And the friend of the man in the one laboratory wanted to use the equipment in another laboratory to see whether it was better in his array. And he couldn't do it because it wouldn't fit in the niches in the array—the template, as it were.

They got together and worked out a set of specifications, and this was an extremely elaborate thing—not simple at all—from the standpoint of variation in detail and multiplicity of detail. They have now published a set of recommended specifications, with dimensions, including voltages and currents and other things, many of which I am not familiar with. And the fear among these chaps was that the instrument makers would rise in revolt because they would find their equipment outlawed, and it would not be marketable if there was a widespread acceptance of this suggestion.

On the contrary, there has been relatively little resistance, and the probability is that these instrument manufacturing companies have welcomed this suggestion. They still have an opportunity to compete with each other on the basis of performance. And if the dimensions are the same, then everybody can buy them and use them on an interchangeable and replacement basis.

If a group as authoritative and influential as is represented by the

persons in this room were to formulate and come to agreement regarding a set of specifications for cesium needles, while not everybody would make them and not everybody would use them, I suspect that some or all of the fabricators of cesium needles would follow these specifications. The only manner in which they could compete with each other, therefore, would be on service and price.

DR. CHADWICK: As I understand it, the matter of standardization of procedure involves two elements. One is the actual design and specifications of the needles themselves. And the second is the techniques and procedures by which they are used. And I wanted to raise the question, to what extent is the matter of design and specifications of radium needles in this country currently standardized?

DR. FLETCHER: Before starting with the United States, we could say that throughout the British Commonwealth there is a great deal of standardization and one could say without really being too wrong, that radium therapy in the British Commonwealth is the best in the world.

I do not mean to say there are not some places outside the British Commonwealth that do not have as good radiotherapy centers as the British Commonwealth, but, taking the average, it is still best. This means that you have a great supply of information coming out of the British Commonwealth.

In the United States, there are more and more places—and we are one of them—using the British stocks of needles with very minor modifications.

Concerning gynecological radium treatments, there are a number of places which are using a modification of the Manchester system. We employ a modified Manchester system at the M. D. Anderson Hospital.

A great deal of clinical experience has been acquired. A young man going into radiotherapy might as well adopt the standard types of needles and applicators because he will find a great deal of information available as to their use and dosimetry.

DR. SCOTT: Dr. Fletcher, are there written standards describing the specifications for radium capsules and radium needles concerning a certain length, shape, strength, or kind of material?

DR. FLETCHER: I can give you a copy of our stock, which is similar to the British stocks.

DR. SCOTT: Does anybody in the United States have to conform to these specifications?

DR. FLETCHER: No, sir.

DR. SCOTT: Is there any voluntary effort or organization among the people who sell radium needles and capsules in the United States to conform to this?

DR. FLETCHER: There is a strong move to that. The Radium Chemical Company has had the British type of needle available for years.

DR. SCOTT: In other words, you are telling me this is the only kind of stock they sell in the United States?

DR. FLETCHER: No.

DR. SCOTT: I could order any kind I wanted to?

DR. FLETCHER: They will make you anything you wish, but the British type is the one they will have available most readily and you surely can get it without any problems. However, you can order anything you wish.

DR. MESSERINE: While radium capsules vary widely in dimensions, radium needles are quite uniform all over the world, at least in diameter. The reason for this uniformity is that one needs a wall thickness of 0.5 millimeter of platinum to absorb the primary beta particles. To fill it with radium, the hole in the middle must be at least 0.6 millimeter. This adds up to an overall diameter of 1.6 millimeters. This is already quite a big needle and larger diameters are not used because they would cause undesirable trauma. Radium needles also have a characteristic isodose pattern with a relatively low dose rate at both ends due to the marked absorption in the platinum wall and in the radium itself.

It is easy to make cesium, cobalt, or iridium needles of the same diameter and isodose pattern as radium needles, and this should be done in order to permit the application of the large clinical experience gained with radium. However, one should not close the door to other needle types. Needles with a thinner diameter are probably better clinically because they produce less trauma and are easier to insert. Iridium 192 and cobalt 60, for instance, can be easily made in one-half or one-third the diameter of radium needles.

DR. CHANDLER: What you are saying is that there ought to be a standard technique and equipment, but also the door ought to be open for further developmental work, possibly pointing toward the revision of the standards should some developments lead to better equipment and technique.

DR. STORUM: This is a very interesting discussion because it points out clearly some of the problems that one gets into when he embarks on a program of standardization in a field of science that is still moving forward. One has to be very careful in one's standardization program not to impede further development. And that's really what we are talking about here.

We have a vast experience in the field of radium. We have in cesium, as an example, a possible substitute. But if we are to avoid an enormous number of problems immediately, we need to have

cesium sources that will duplicate the results that we get with radium. And the only way we can do this is to have some sort of standard.

But in setting up such a standard, we must be very careful not to impede such work as that of Dr. Henschke. This, I think, is important to remember in any developing standardization program.

DR. ROLAND: May I at this point review interstitial radium therapy from its inception to the present time and point out which of the developments are sacrosanct?

The first rule is that a linear intensity of 0.66 milligram of radium per centimeter for full-intensity needles and 0.33 milligram per centimeter for half-intensity needles has proved most satisfactory for general use. This follows from Regaud's work in Paris and has not been improved upon.

The second rule is that 1 week overall time is optimal. This rule also follows from Regaud's practice. If needles are left *in situ* for more than a week, they lose their geometric pattern as the tumor begins to disintegrate. As Dr. Fletcher pointed out this morning, an implant that is completed in 3 or 4 days comes to grief with necrosis or recurrence. All our knowledge of optimal dose is based on approximately 7 days overall time, and biologically equivalent doses at other times are not firmly established.

The third rule is that there should be homogeneous tissue dose and that the dose stated should be the tissue dose and not milligram hours. Dr. Paterson in Manchester introduced this concept and increased the 5-year survival of mouth cancer from 25 to 52 percent by this step alone.

The fourth rule is that the optimum volume for implantation is one that is as small as possible, giving only a centimeter or less margin on the edge of the tumor. Restriction of volume irradiated increases the 5-year survival.

The fifth rule is that for each site and volume irradiated there is an optimal dose. Increase or diminution of the dose by as little as 10 percent causes a significant increase in necrosis or recurrence.

Further improvements in the precision of radium implants are possible, with consequentially better clinical results. Using a computer for detailed isodosing of implants, Fletcher has demonstrated most convincingly that necrosis occurs in zones of excessive dosage and recurrence takes place in areas of under dosage.

Whilst radium substitutes are desirable, it must be remembered that any variation of the factors long employed and established is made at some hazard. For example, even with the hard quality radiation from radium one has to accept a certain number of cases of bone necrosis when implants are carried out near bone. Theoretically,

if a soft radiation is used the proportion of bone necrosis will be increased.

There is another danger in moving to a softer quality radiation and that is the increase in the relative biological efficiency. Since 1950, I have been trying to develop iridium as a radium substitute and have noticed a greater degree of reaction than expected for a certain tissue dose. I have also had the misfortune of failing to cure a small carcinoma of the lower lip by iridium implantation. So moving towards iridium is a slow process pursued at some hazard—namely, of not knowing to the order of ±10 percent what is the optimum dose.

DR. MENSCHIK: I think that standardization is actually a secondary problem. The primary problem is to decide whether there is a satisfactory substitute for radium, which, as was pointed out, can be extremely hazardous. I feel that if radium were to be discovered today, the AEC would not permit its use.

Cesium 137 has two key advantages over radium as a substitute in conventional needles and capsules: (1) It is much safer in case of breakage of the capsule; and (2) Protection is simplified because the half-value layer in lead is only one-half of that for radium. The lower energy does not bring any practical problems in dosimetry or in biological effect.

These advantages of cesium over radium are not great enough, in my opinion, that one should force a physician or an institution that owns a radium stock adequate for its work to change from radium to cesium. However, wherever a completely new stock is required, cesium 137 should be used in preference to radium.

Serious consideration, however, should be given by all institutions to afterloading techniques, for which iridium 192 and cobalt 60 are the first choice, since radium and cesium 137 cannot be produced in sizes that are small enough.

This essentially is the recommendation of the Conference at Vienna, and I would recommend it for adoption by this conference, too.

DR. PARKER: If you had asked me to talk first, I would have said exactly what Dr. Henschke has said. I think it is excellent. And if we could recommend and make available in the form of a handbook, information on cesium needles and cesium tubes that are exact duplicates of the radium needles and tubes, we can fall back on the experience acquired with radium. It would be unwise to shift to many isotopes without making available the experience of the past.

DR. MESSERER: I think that besides the search for better isotope sources for needles and capsules for removable applications, the question of radioactive seeds for permanent implants should receive consideration by this conference.

Permanent implants are of great value in cancer therapy: (1) For

palliative cancer therapy, especially for the frequent small skin recurrences in head and neck cancer and in breast cancer. These can be readily implanted under local anesthesia without hospitalization. This is not only very economical but is usually welcomed by the patient, who at this point tends to dread another hospitalization; (2) For treatment of unresectable tumors unexpectedly encountered during thoracic and abdominal operations. This is a daily occurrence in a cancer hospital. For instance, in approximately one-half of all operations for lung cancer, the tumor is found unresectable. A permanent interstitial implant at this time permits one to deliver a much higher dose than is possible by external radiation therapy and to deliver it precisely to the right spot, since one holds the cancer in his hand. Thus, an otherwise useless and potentially dangerous procedure can be converted into an effective therapeutic attack.

At the Memorial Center, we have done more than 500 implants of this type in bronchogenic carcinomas alone. All these implants have been well-tolerated, have consistently produced good tumor regression, and have resulted in a few cures in otherwise hopeless cases.

For permanent implants we have used, besides radon 222, gold 198, and iridium 192 seeds. The two main drawbacks of radon seeds are that they are expensive ($5 per 1-millicurie seed in the United States) and that protection is difficult because of the ½-inch half-value layer in lead. Gold 198 seeds are less expensive ($1 in the United States) and protection is easier than for radon seeds, since the half-value layer in lead is only approximately one-tenth of an inch. However, the shorter half-life of the gold 198 seeds (2.7 days versus 3.85 days for radon seeds) is a definite disadvantage. The radiation is delivered in a relatively short time, and this appears less favorable biologically than the relatively longer time during which radon seeds deliver the dose. In addition, the shorter half-life is a practical disadvantage since the gold 198 seeds have a suitable strength for a shorter time than radon seeds. Iridium 192 seeds have been used by us for permanent implants in 357 patients, and some of our best clinical results have been accomplished with them. It is our impression that the long, protracted radiation (which the iridium 192 with its long half-life of 74.5 days produces) is advantageous, especially for slow-growing tumors. Iridium 192 seeds are also most economical, since they retain a suitable strength for at least a month, so that usually all the seeds which have been ordered can be used. In addition, iridium 192 seeds share with gold 198 seeds the ease of protection since the half-value layer in lead is only one-tenth of an inch. The great problem with iridium seeds, however, is that the implanted patient remains radioactive for a long time and that radiation safety precautions are often necessary for months.

For permanent implantation, we have developed an implantation technique in which, initially, empty needles are inserted in and around the tumors. A special instrument with a depth gage is then attached to each needle in turn, and through it several seeds can be spaced along the needle track. With this technique and instrument, the radiation exposure, especially to the hands of the operator, is greatly reduced and much more accurate implants are possible. However, the problem of radiation exposure of personnel from the implant inside the patient remains and constitutes the key obstacle to the wider use of permanent implants. The only way we see to overcome this problem is the use of low-energy isotope sources. In the [following] table we have listed, besides the presently used isotopes (radon 222, gold 198, and iridium 192), a number of isotopes which we have currently under development for seeds for permanent implants. The three listed isotopes, namely, xenon 133, cesium 131, and iodine 125, have their main lines around 30 Kev. and their half-value layer in lead is less than one one-thousandth of an inch. With very thin metal foils, complete radiation protection can be achieved. These three isotopes also offer a wide choice of suitable half-lives. The developmental work carried out so far indicates that suitable seeds can be produced with xenon 133, cesium 131, and iodine 125. We believe, therefore, that every effort should be made to promote the further development of these low-energy seeds, and we feel that in this way permanent implantation will come into much wider use as soon as such seeds are available commercially.

Isotope	Half-life (days)	Half-value layer (inches)
Radon 222	3.84	½ Pb
Gold 198	2.7	⅛ Pb
Iridium 192	74.5	⅛ Pb
Xenon 133	5.3	
Cesium 131	9.8	<1/1000 Pb
Iodine 125	60	

Coming back to the immediate problems, I think that radon should continue to be used, and I don't visualize any problems. The only substitute available commercially is gold 198 seeds, which have the advantage of lower cost and better protection and the disadvantage of a shorter half-life. In contrast to radium, which can really be dangerous, radon is no more hazardous than gold 198.

DR. SCHULZ: Except the risks in the pump room are considerable, aren't they? It doesn't bother you and me, but it bothers the fellows down there working with it.

DR. HENSCHKE: It bothers us, too, but with proper care and experience a radon plant can be operated without excessive exposure.

DR. SCHULZ: We use gold grains.

DR. FLETCHER: You have radon seeds, why not use them?

DR. SCHULZ: One reason is because of the lack of reliability of calibration.

DR. HENSCHKE: Each radon seed should be calibrated. We have a semiautomatic calibration system. Actually, it is also desirable to calibrate each gold 198 seed individually.

In my opinion, one should not regulate against radon seeds but should apply the same radiation safety regulation as for gold 198 seeds.

DR. MORGAN: In the State health department, though, there will be the additional problem of the protection of the pumping people; and, hence, there is need for protection standards associated with this. And, as far as I know, there are no protection standards on radium pumping facilities at the present time, are there?

MR. VILLFORTH: There are no specific standards, but basic radiation procedures would be applicable.

DR. SCHULZ: There is one advantage to radon, you know. If you put several gold grains in the patient and send her home, she constitutes a risk to whoever lives with her. But using radon seeds, there is no legal risk.

DR. HENSCHKE: Up until now. The fact that radon seeds did not require a license is undoubtedly one of the main reasons why they are more widely used than gold 198 seeds, in spite of the much higher price ($85 for a 1-millicurie radon seed versus $1 for a comparable gold 198 seed). But with State regulating agencies now requiring licenses for radon, too, there will probably be a drop in the use of radon seeds.

DR. ROESSLER: I certainly think, Dr. Henschke, that we should include radon along with radium in our discussions. And, on the basis of what you are saying, apparently radon seeds are still being used, and profitably so. We should consider safety measures for radon plants and perhaps even for radon seeds.

DR. WOLASH: I have had unfortunate experience in the inaccuracy of radon seeds supplied by manufacturers. And I don't know that I would oppose too much a recommendation to ban radon. Personally, I use radon perhaps about a third or a quarter as much as radium. And because of the difference in half-life, I have been a little bit loath to move to gold grains routinely.

It is also a personal point of view that an awful lot of damage is perhaps being done with radon seeds being badly applied by inexpert people.

DR. TER-POGOSSIAN: Yes, but still, Dr. Boland, I don't believe we can ban this form of therapy. We can control it. We can make it safe or try to make it safe. But I don't believe that you can ban it as such.

DR. BOLAND: If we only had some central agency that, to a limited number of approved people, would give out radon seeds of reliable strength, this would be a great boon.

DR. TER-POGOSSIAN: There is no reason why we couldn't specify the accuracy of the calibration on both radium sources and radon sources. That would be certainly very much in line.

MR. VILLFORTH: There is another group of sources that is of interest—the dermatological plaques. These sources, by virtue of the fact that they have a very thin covering of Monel metal, are almost impossible to seal. Even some brand new ones have been found to be leaking. So here is another application that needs some exploration.

DR. SCHULZ: Strontium 90 plaques can be made perfectly safe, and do exactly the same thing, and thus are an excellent substitute for radium.

Conclusion Number 4

It is further recommended that research be directed to the development of better radiation sources for brachytherapy. The possibility of fabricating better and safer sources with presently used radionuclides, including radium, should be considered.

In Discussion:

DR. ROLAND: While many radium needles have been found to leak, the vast majority of needles of modern manufacture do not leak. And furthermore, the international standards and other larger substandards have been encapsulated for 40 years. Although there is theoretically an increase in the pressure of the gas in these sources, there has been no leakage. Why is it some leak and some don't?

MR. VILLFORTH: This is absolutely correct; however, I question your statement that present day sources do not leak. I do know of a shipment of sources that were recently reencapsulated, and one of them was received leaking. You are correct that, in general, the newer doubly-encapsulated sources, with screw caps rather than the friction caps, are a better type of source.

The problem of why some leak and some do not may be explained by the variation in the amount of moisture in the salts when they were encapsulated. If there is any moisture or water of hydration present in radium salts, then the pressure buildup from the dissociation of water and the production of hydrogen and oxygen gas can amount, according to Dr. Morgan of California [*Amer. J. Roentgenol.*, vol. 85, pp. 949–954, 1961], to a pressure of several hundred atmospheres per year.

Now, this water of hydration is more frequently present in the soluble salts—the chlorides and bromides. Madame Curie, herself, identified this as a potential problem early in her research; and extreme care was taken in her laboratory in the preparation of standards to make sure that these were heated well above the temperature where the water of hydration would be driven off.

After the First World War and into the twenties, there were many smaller radium processing companies, who may not have understood the importance of this heating or may not have been interested in carrying the process to completion to guarantee that the excessive pressure problem would not occur.

DR. TER-POGOSSIAN: There are no radium sources encapsulated in the United States now. All the radium which is sold through the Radium Chemical Company is encapsulated, I believe, in Belgium.

MR. VILLFORTH: You are correct. Radium Chemical Company will never create a situation where they expose the salts. A ruptured source is shipped to Belgium for reencapsulation without being touched.

To the best of my knowledge, there is no radium processed in the United States.

MR. BERMAN: Mr. Chairman, are the problems really inherent in the isotope, or are they caused by the particular chemical form of the isotope and the encapsulating technique which has been routinely used? We have worked with materials which have problems at least of the same order of magnitude as radium—some of them orders of magnitude worse. Polonium 210 is a rather good case in point, I think, in terms of helium buildup, and, for want of a better term, "creep."

We have routinely available polonium compounds and sources that we feel are inherently safe as long as they are used as intended. This didn't come easily but, nevertheless, it has been our experience that, if there is an impetus to develop a particular form of isotope to eliminate some of these potential hazards, such as "creep," it can be done. It has been done for materials considerably more difficult to work with than radium.

DR. SCOTT: I can't answer this question, but if you can make radium safe, that would be fine.

DR. BERMAN: This gets to the other point made by Dr. Henschke, that perhaps if the AEC had the responsibility for radium its use wouldn't be permitted today. I think perhaps that if the AEC had this responsibility for radium, considerably greater work on making radium needles and radium sources inherently safer would have taken place.

DR. HENSCHKE: Not if a safer radioisotope is available, which is clinically just as useful as radium.

DR. SCHULZ: We have been talking here about finding things which do not share the risks and the hazards of radium. We haven't said anything about whether or not there is any possibility of making this useful material, radium, more safe than it is now. What funds have people expended and what research has been done into the ways and means of reducing the risks?

I am just thinking, for instance, how cesium is sintered in a ceramic. If the same thing could be done to radium, then the risks of spillage would be no greater than those inherent in cesium.

MR. BERMAN: I am not sure I wasn't alluding earlier to the complex glass of cesium or some ceramic form of cesium which was developed

in response to a need. This need had nothing to do with the medical profession. The need arose from an interest in uses of enormous sources of cesium in unattended operations where one could postulate a credible accident of capsule rupture, in which case one would like the additional barrier of containment with a lower leach rate material. That's why we went from cesium chloride to a cesium polyglass or this high fired decalso-cesium complex. We have done this, of course, for other isotopes. Strontium is an excellent case in point.

DR. SCHULZ: Why couldn't that be done for radium?

MR. NEWMAN: This was the point that I really wanted to make. It was that the AEC, in meeting its responsibilities in the production of artificial nuclides since 1946, has had a continuing research and development program, while we ran (and for all practical purposes are still running) what might be termed a commercial operation. The impetus for the R & D wasn't purely commercial impetus.

By that, I mean that the annual R & D budget associated with our radioisotopes development, production, and distribution effort is considerably in excess of what it would be if one used the normal commercial factors. And it has proved very successful, I think, in terms of the numbers and products we have developed and the fact that we can, should the need arise and the need be strong enough, essentially tailor-make materials to a particular type of application or to satisfy a particular type of need.

You have never found this, of course, in the radium business, which essentially has been a purely commercial operation. There has never been the same kind of research support to improve radium products.

In terms of support of an R & D nature, the Atomic Energy Commission initiated, over a year ago, a program of a continuing nature at Oak Ridge National Laboratory, which would have several purposes. First, through an examination of the applications of various sealed sources of radiation, both industrial and medical, it would attempt to classify sealed sources by the types of applications for which they might be used.

The second part of this program is to develop reliable sealed source safety testing techniques that manufacturers and the various regulatory agencies could use with some degree of confidence in insuring that the continuing supply of sealed sources met the various categories or classifications of use to which they might be put. So at least a start has been made.

I should point out that, for historical legislative reasons, the Commission has done little in this program with the naturally occurring radioactive materials such as radium. Our interest has of necessity been primarily concerned with the artificially produced isotopes.

Conclusion Number 5

The development of new techniques, such as afterloading procedures, to reduce unnecessary personnel exposure in the therapeutic application of radionuclides should be supported and encouraged.

In Discussion:

DR. HENSCHKE: I would like to demonstrate a model of our new remote afterloader, which is described in detail in *Radiology* [vol. 83, pp. 344–345, 1964]. An empty applicator is first inserted. The patient is then brought into a shielded room, in which three small, strong sources are stored in a well-protected wall container. This container and the applicator are subsequently connected with plastic tubes. Through these tubes the three sources, which are connected to steel cables, are then remotely inserted from a control stand outside of the room. The sources can also be remotely moved back and forth during the treatment to stimulate linear sources of any desired length and of any desired loading pattern.

With this remote afterloader, radiation exposure to personnel can be completely eliminated and no transport of the sources through the hospital is required. Intracavitary radiation therapy thus becomes as simple and safe as external radiation therapy.

DR. SCOTT: That's very ingenious. Thank you very much, Dr. Henschke.

DR. FLETCHER: Mr. Chairman, as Dr. Henschke has mentioned the afterloading technique, I think it would be appropriate to say that in gynecology we have designed afterloaded applicators to accommodate the conventional radium sources. For the last 8 years at the M. D. Anderson Hospital, we have used afterloading applicators excepting when a special type of tandem is needed. I would say that nine-tenths of our gynecological implants are done with afterloading applicators.

The bladder and rectal dosage measurements are taken with microcurie radium sources. The films are taken with dummies.

DR. SCOTT: We have been talking about afterloading techniques. This means protection of the operator primarily. Just what is the order of magnitude of risk to the operator? Is this really a signifi-

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cant thing or are we picking flyspecks out of pepper in this whole business?

DR. FLETCHER: Of course, it depends on the quantity of radium in the application, and I can give you some figures. The radiotherapist for an average radium implant used to get 12 millirocntgens, the X-ray technician 8 millirocntgens, the anesthesiologists 6 millirocntgens, and the recovery room nurse 11 millirocntgens.

With afterloading applicators the radiotherapist is now getting 2 instead of 12 millirocntgens. The X-ray technician who takes the film, anesthesiologists, and recovery room nurses get no exposure. In doing 15 to 20 gynecological implants per week, multiply 12 millirocntgens by 20, which is a significant exposure. Of course, personnel were rotated, but it was not uncommon that the 3-month assignments would have to be terminated earlier because an individual had reached the permissible dose before the end of the 3 months.

In gynecology, the afterloading tandem is clearly superior. Why not take advantage of protection?

Now, for chest wall implants, as I have said, we are using iridium because radium is prohibitive. Once an operator got close to a 1-roentgen exposure.

DR. ROLAND: You need two operators.

DR. FLETCHER: Yes, two operators used to share the exposure.

DR. ROLAND: You could do it in 8 minutes, actually.

DR. SCOTT: Basically, there is no question of using a technique that will cut down exposure.

DR. FLETCHER: With afterloading techniques, not only can one take time and use the length of needles which is appropriate, but the sources are also more flexible. There is no reason not to use afterloading techniques when they are clearly better.

I was a bit conservative, originally, but we are all sold on it now.

DR. MENSCHIK: It is true that an institution which does not use much interstitial and intracavitary radiation therapy can surmount the radiation safety problem by good organization. However, the fear of radiation is so rampant today, especially among personnel in the operating and recovery rooms, that it is a great advantage to eradicate the problem completely by afterloading techniques.

DR. FLETCHER: This is a psychological factor that is quite worthwhile. There is a great deal of scare, right or wrong, of radiation exposure. You have said, Dr. Schulz, "What is the meaning of maximum permissible dose?". But let anybody get it, and you really have a problem in your hospital.

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